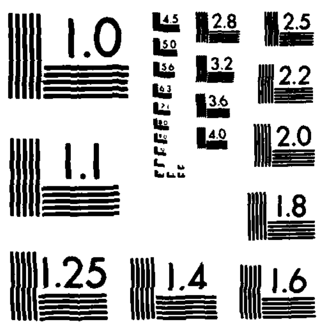
AD-A152 074 AVIONICS TECHNOLOGY AND SYSTEMS DEVELOPMENTS TECHNICAL PAPER ABSTRACTS TE..(U) AMERICAN DEFENSE PREPAREDNESS ASSOCIATION ARLINGTON VA 02 DEC 83 1/1

UNCLASSIFIED F/G 9/5 NL

END
FILMED
DTIC

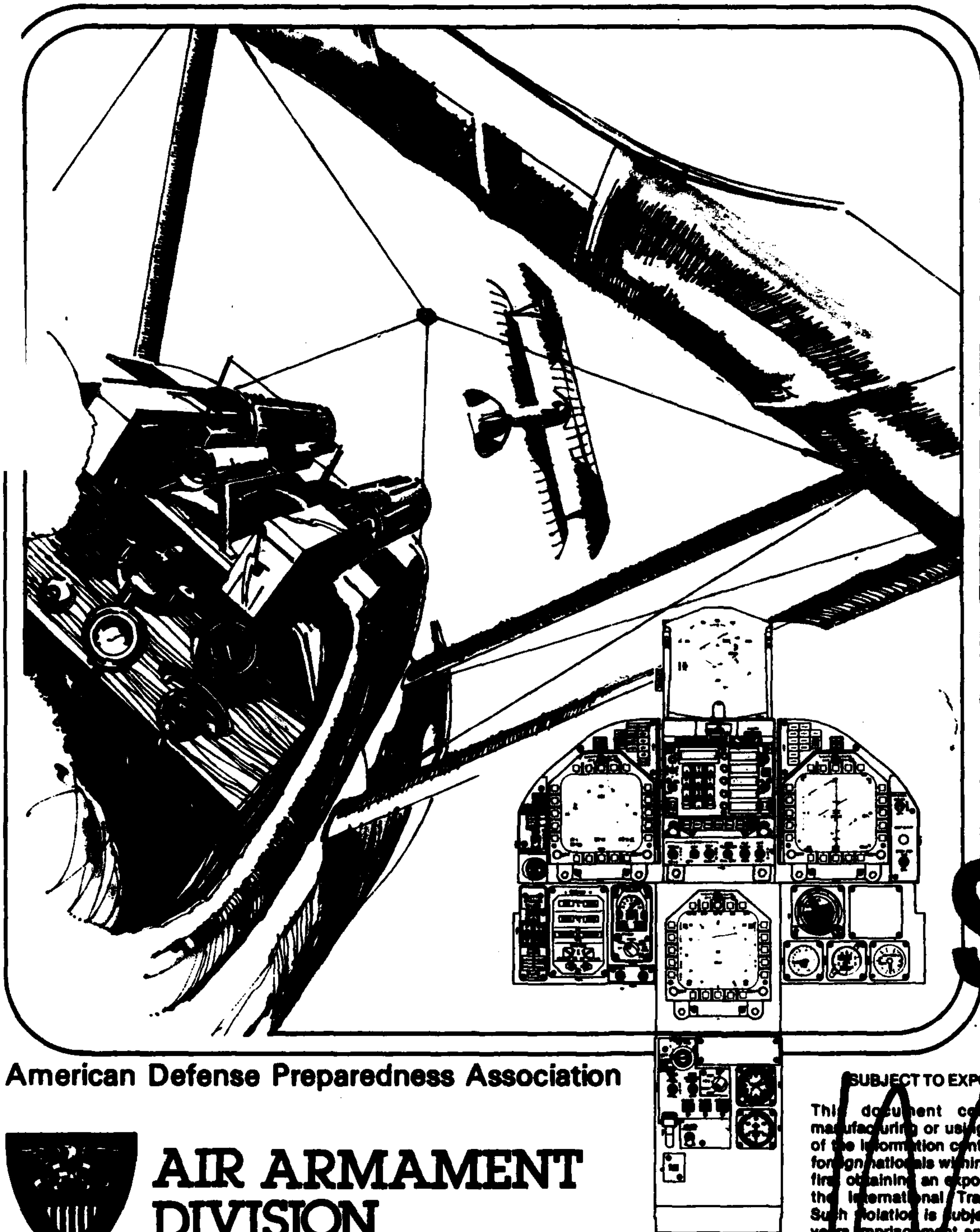


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

1983 Technical Meeting
November 30, December 1 and 2

Avionics Technology and Systems Developments
Technical Paper Abstracts

AD-A152 074



This document has been approved for public release and sale; its distribution is unlimited.

DTIC
SELECTE
APR 1 1985
S A

American Defense Preparedness Association

AIR ARMAMENT DIVISION

AVIONICS SECTION

SUBJECT TO EXPORT CONTROL LAWS

This document contains information for manufacturing or using munitions of war. Export of the information contained herein, or release to foreign nationals within the United States, without first obtaining an export license, is a violation of the International Traffic-in-Arms Regulations. Such violation is subject to a penalty of up to 2 years imprisonment and a fine of $100,000 under 22 USC 2778.

Include this notice with any reproduced portion of this document.

Printed for the American Defense Preparedness Association

MCDONNELL DOUGLAS

DTIC FILE COPY

84 08 10 043

AVIONICS SECTION STEERING COMMITTEE

Section Chairperson
Robert L. Harris, Jr.
Emerson Electric Company

Deputy Section Chairperson
Phillip O. Brown
McDonnell Aircraft Company

1983 Technical Program Co-Chairperson
Francis Lueking
Naval Air Systems Command

Section Recorder
Daniel F. Wiener II
U.S. Army

Phillip O. Brown
McDonnell Aircraft Company

Col. Paul H. Scordas (Ret)
Hq. ADPA

INDUSTRY REPRESENTATIVES

George L. Cohill
Bell Helicopter Textron

Donald E. Dewey
Teledyne Systems Company

Andrew S. Frohlick
Teledyne Systems Company

Jerold Gard
Kaiser Electronics

Murray Goldstein
Singer Company, Kearfott Division

Myron Greenbaum
ITT Avionics Division

Ken Kenworthy
Defense Management, Inc.

Neil Kessler
Northrop Ventura Division

Dr. Adam Kozma
Environmental Research Institute of Michigan

Dr. Samual Musa
E-Systems

Dr. John C. Ruth
General Dynamics

Robert M. Stetson
Sanders Associates, Inc.

Barbara B. Wyatt
General Dynamics

U.S. NAVY REPRESENTATIVES

Commander Jerry Plum
Naval Air Systems Command

Lucien Daouphars
Naval Air Development Center

U.S. ARMY REPRESENTATIVE

Dr. Gene Marner
U.S. Army Aviation Research & Development Command

U.S. AIR FORCE REPRESENTATIVES

Louis J. Urban
Aeronautical Systems Division

Dr. Jesse C. Ryles
Air Force Avionics Laboratory

(1)

1983 TECHNICAL PAPER ABSTRACTS

AVIONICS SECTION

AMERICAN DEFENSE PREPAREDNESS ASSOCIATION

AVIONICS TECHNOLOGY

AND

SYSTEMS DEVELOPMENTS

NAVAL AIR STATION
JACKSONVILLE, FLORIDA

NOVEMBER 30, DECEMBER 1 & 2, 1983

PRINTED BY:

MCDONNELL AIRCRAFT COMPANY
P.O. BOX 516
ST. LOUIS, MISSOURI 63166

FOR

AMERICAN DEFENSE PREPAREDNESS ASSOCIATION
ARLINGTON, VIRGINIA

PREFACE

One of the most important services provided by the American Defense Preparedness Association is that of creating forums for the exchange of information among science, industry and government on issues which affect our national defense preparedness. The Avionics Section of the Air Armament Division holds an annual technical meeting specifically to exchange ideas, experiences, and technology pertaining to Avionic subjects. The majority of the critical avionics topics are classified; therefore, the technical forum provided must be a classified meeting.

The Avionics Section's technical meeting budget is derived from current meeting registration fees. These do not include the costs associated with publishing classified proceedings. As an alternate, the Avionics Section Steering Committee asks for industry volunteers to print extended unclassified abstracts. A technical abstracts document is thus made available to each attendee before the meeting. This technical meeting record has a corollary benefit. It provides a premeeting introduction to the technical subjects thereby promoting better communications between the speaker and audience.

The speakers have been asked to consolidate multi-year activities on complex avionics issues into twenty minute presenstations. We compound that request with "Provide us an unclassified extended abstract of three to five pages." These unclassified abstracts prepared by the speakers are published here.

The 1983 Technical meeting record will be available for a limited time from the American Defense Preparedness Association, Rosslyn Center, Suite 900, 1700 North Moore Street, Arlington, Virginia, 22209.

Phillip O. Brown
November 1983

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

F-15 AN/APG-63 High Resolution Radar
DT&E Flight Test

John M. Deloney, Captain, USAF
6510 Test Wing/F-15 CTF
Edwards AFB, CA

This paper briefly presents the results of the F-15 AN/APG-63 High Resolution Radar (HRR) Development Test and Evaluation (DT&E) flight test program. This test program was conducted as a joint Government and Contractor effort with participating representatives from the Air Force Flight Test Center (AFFTC) F-15 Combined Test Force, McDonnell Aircraft Company (MCAIR), and Hughes Aircraft Company/Radar Systems Group (HAC/RSG). The historical background leading up to this program, the program scope, the test item description, the test results, and a summary are presented.

The F-15 AN/APG-63 HRR development began as a joint Independent Research and Development effort by MCAIR and HAC/RSG as part of their Advanced Fighter Capability Demonstrator program. HRR mapping was developed and demonstrated by the contractors during flight tests between November 1980 and August 1981. In 1982, a Ford Aerospace and Communications Corporation (FACC) Pave Tack pod was integrated with the HRR and flown during flight tests by the 3246 Test Wing at Eglin AFB, Florida. In late 1982, the FACC Advanced Fire Control pod, featuring Forward Looking Infrared (FLIR) imaging and laser designation/ranging capability was integrated and flown by the contractors at Edwards AFB, California.

The AFFTC HRR test was conducted as part of the avionics evaluation of the proposed F-15 Dual Role Fighter (DRF), a derivative F-15 with air-to-ground (A/G) night and in-and-under-the-weather capability, and air-to-air (A/A) capability. Three training and 14 test sorties (for a total of 31.7 hours) were flown between 10 December and 28 February 1983 at the AFFTC, Edwards AFB, CA.

The test aircraft was a preproduction F-15B equipped with prototype Conformal Fuel Tanks, and it was modified to accommodate the HRR and an integrated aft crew station (controls and display system). The aft crew station featured two avionics control handles and four multifunction displays (Figure 1). The aircraft contained a digital electronic moving map (Tactical Situation Display), a modified Mission Computer (MC), a modified Inertial Navigation System (INS), and a modified Armament Control Set. These modifications provided release capability and sequencing from the five weapon carriage stations (Figure 2).

The HRR was a modified AN/APG-63 radar in which the A/A software was replaced by HRR A/G software, the Radar Signal Processor was replaced by a Programmable Signal Processsor, and

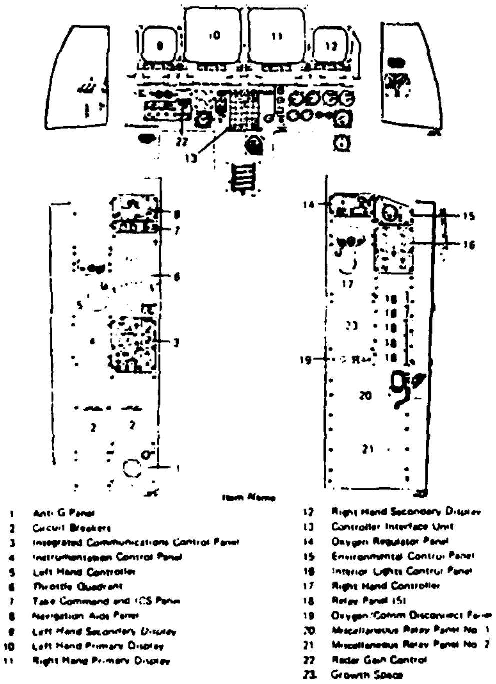


Figure 1. Aft Crew Station Arrangement

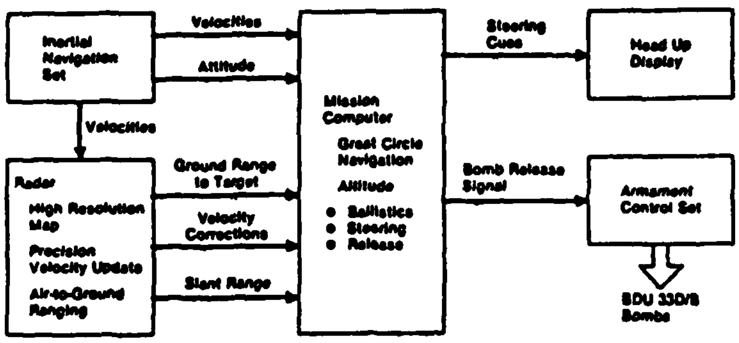


Figure 2. Relationship of the HRR Avionic Systems

the bulk memory of the Radar Data Processor was increased from 98K to 392K 24-bit words. The HRR A/G software incorporated Synthetic Aperture Radar (SAR) technology to improve azimuth resolution and it used digital pulse compression techniques to improve range resolution.

The HRR had three modes of operation: Precision Velocity Update (PVU), High Resolution Mapping (HRM), and Air-to-Ground Ranging (AGR).

The PVU mode provided a more accurate estimate of aircraft velocity than that provided by the INS. The PVU velocities were used by the radar to determine the angular position of each Doppler processed azimuth element in the HRM mode. This enabled the HRR to provide improved North and East range information to an HRR designated target. These velocities were also used to update the INS velocities for navigation and weapon delivery solutions by an algorithm within the MC called the "terminal navigator".

The HRM mode used SAR techniques to collect data off axis from the aircraft's velocity. After onboard electronic processing, the radar map was displayed as though the aircraft were directly above the area being mapped. THe orientation was such that the farthest feature mapped appeared at the top of the display and the nearest feature at the bottom (Figure 3).

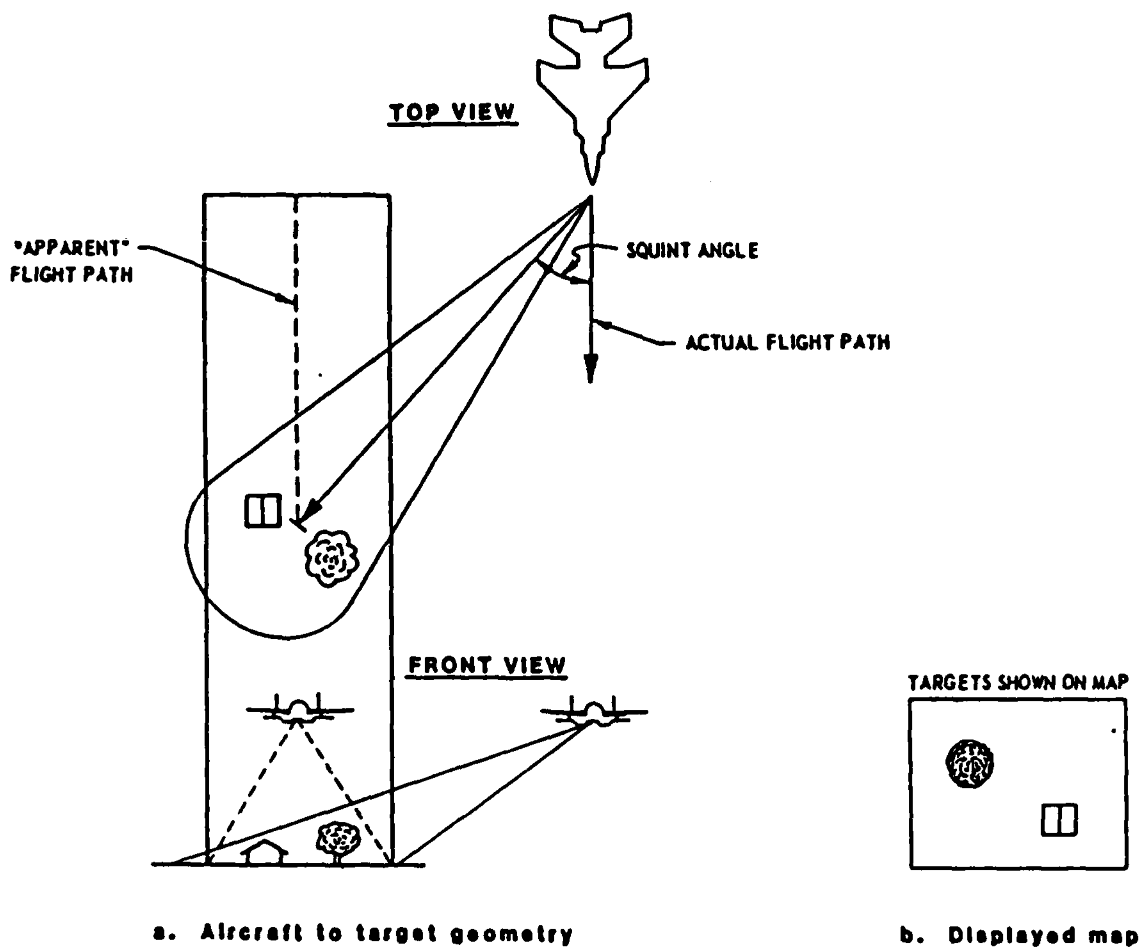


Figure 3. Flight Path Geometry and Radar Map Display

The HRM mode provided eight different mapping resolutions and two mapping formats, Planned Position Indicator (PPI) and patch map. The 0.67 NM patch map provided the best resolution. Full maps consisted of 480 azimuth and 480 range picture elements (pixels). The ground distance covered by one pixel was equal to the resolution selected. Ground returns within ± 8 degrees of the velocity vector were not processed for display.

The AGR mode provided slant range and elevation angle to an HRR designated target. These data were used to derive the aircraft relative altitude above the target. AGR was automatically commanded 10 seconds before weapon release. If the AGR data were not available, the HRR system could deliver a weapon using baro altitude calculations. It is important to note that the radar was passive between the time the HRR map was constructed and frozen and the time when AGR occurred.

The resolution of the HRR was evaluated by mapping an L-shaped array of nine triangular radar corner reflectors. The reflectors were constructed of sheet aluminum, 12 inches on a side, and had a Radar Cross Section (RCS) of 39 square meters at X-band. The range reflectors were mounted on wooden poles of ascending height to allow shallow graze angle illumination without obscuration. The range, graze angle, squint angle, and direction of offset were varied to determine their effects on the range and azimuth resolution.

The resolution of the HRR in range and azimuth was 8.5 feet out to 9.8 NM, 17 feet out to 19.8 NM and 40 feet out to 48 NM.

To evaluate maneuvering effects on map quality, the aircraft was maneuvered up to plus 40 degrees of pitch, $\pm$ 60 degrees of bank, and load factors greater than three while constructing HRR maps.

It was determined that azimuth (squint angle) and airspeed had no apparent effect on map quality. These two parameters did affect the time required to construct an HRR map. Larger squint angles and higher velocities produced faster HRR maps. Altitude (graze or elevation angle) had no effect on map quality as long as the radar had line-of-sight (LOS) to the target and the radar elevation angle was below minus 0.3 degrees (minus indicating downward).

Aircraft attitude and maneuvering effects were evaluated on a limited basis. Map quality degradation was not apparent during maneuvering except when the area being mapped was brought through the aircraft's velocity vector. In these instances a blank area appeared in the radar map corresponding to the $\pm$ 8 degree blind zone about the velocity vector. Load factors greater than three produced radar array mismatches and degraded radar maps. However, this was not considered a significant limitation.

The "multi-look" two function (two radar looks at the area mapped) provided no significant increase in map quality over one radar look. Multi-look two was seldom used due to the increased time required to construct an HRR map. The map quality produced by one radar look was satisfactory.

The ability of the HRR to detect and identify fixed tactical targets was evaluated by mapping the targets from approximately 1000 feet above ground level (AGL) and then mapping them in a step down of altitudes to 700, 500, and 300 feet AGL.

The results of this portion of the evaluation were satisfactory. (Actual results are classified CONFIDENTIAL.)

Sixty BDU-33 D/B practice bombs were dropped during the evaluation to determine the overall HRR system accuracy at the weapons release point. All weapon deliveries were level, automatic releases from 500 or 1000 feet above ground level (AGL) and approximately 500 knots groundspeed. The target was a 20-inch radar corner reflector (300 square meter RCS).

The sequence of events that occurred in a typical HRR blind weapon delivery are as follows. Approximately 14 NM from the target, the air-to-ground master mode was manually selected and a PVU accomplished (altitude between 800 and 1000 feet AGL and groundspeed between 380 and 480 KGS). An HRR 3.30 NM patch was automatically initiated outside 10 NM at the same altitude and airspeed. Inside 9.8 NM, a 0.67 NM patch map (8.5 ft resolution) was constructed, the map display was frozen, and the aircraft was turned toward the target (Figure 4). The weapons systems officer designated the target with a cursor while the pilot adjusted the altitude and groundspeed to the desired values. After target designation, the pilot followed the steering commanded on the Head-Up Display. The HRR, passive since the display was frozen, was automatically commanded to the AGR mode approximately 10 seconds prior to bomb release. The pilot then depressed the bomb release button until an automatic release occurred.

The results of the weapon delivery profiles were satisfactory. (The actual results are classified SECRET.)

Two level level training routes were flown to evaluate the usefulness of the HRR for enroute navigation. Instrument Route (IR) 203 was flown at an altitude of 500 ft AGL.

It was determined that the HRR was of limited use for enroute navigation. The inability to make a real-time radar map of the area directly in front of the aircraft (the HRR had a $\pm$ 8 degree blind area off the aircraft velocity vector) was detrimental to the use of the HRR to provide navigation information. The time delay in generating HRR maps did not allow the aircrew to know where they were at the map display time. This was unsatisfactory for high speed and low altitude navigation. For use in

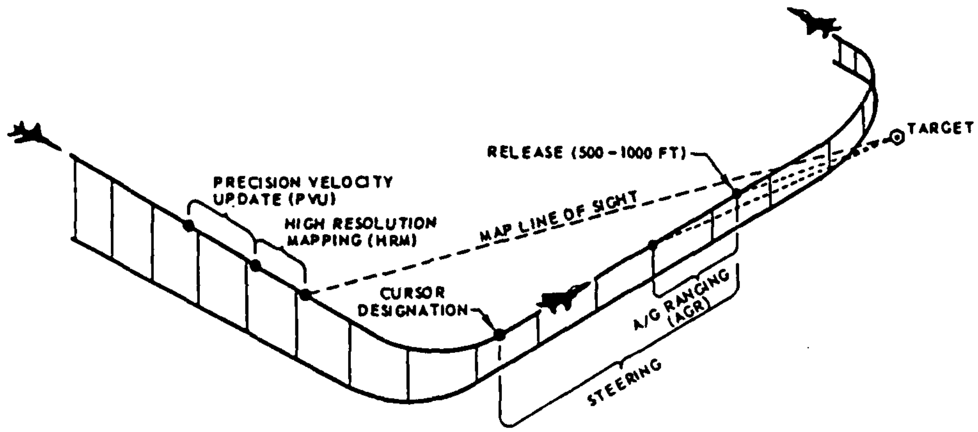


Figure 4. HRR Blind Weapon delivery Profile

enroute navigation, an aircraft with an HRR should have a real-beam, real-time, Planned Position Indicator (PPI) radar display.

Though the HRR was unsatisfactory by itself for enroute navigation, it could accurately update the INS to within 73 feet of the actual aircraft position.

In summary, the features of the AN/APG-63 HRR system afford the F-15 a unique capability not found in any other tactical fighter. The HRR required only line-of-sight to the target to make usable maps, and it demonstrated the capability to detect tactical targets from very low altitudes, low grazing (elevation) angles, and long ranges. During blind weapon deliveries, the HRR was passive from final frozen map construction until 10 seconds before weapon delivery, thus providing a lower probability of detection. Its demonstrated blind bombing capability was satisfactory. The HRR was tested in rain, snow, and clouds with no apparent degradation. Previous testing demonstrated the HRR's ability to cue other onboard sensor systems. For these reasons, the HRR would significantly enhance the air-to-ground capability of tactical fighter aircraft.

AFTI/F-16: An Integrated System Approach to Improved Combat Effectiveness

Lt. Col. A.J. Bianco, USAF

and

F.R. Swortzel, AFWAL/FII
Wright-Patterson AFB, OH

The AFTI/F-16 Advanced Development Program is developing and flight validating advanced technologies which improve fighter lethality and survivability. The capability is achieved by the integration of mission task-tailored digital flight controls with a director-type fire control systems and advanced target sensor/trackers. A key thrust is the evaluation of automation with respect to weapon delivery tasks.

TALONS Flight Test Program

R. Rubino, D. Pratt, and Dr. L. Kosowsky
Norden Systems, Norwalk, CT

and

E. Fliegler, Electronics R&D Command
Adelphi, MD

1. Introduction - A 95 GHz millimeter wave radar has been fabricated for a joint Air Force/Army flight test demonstration which commenced January 1983. The Tactical Avionics for Low Level Navigation and Strike (TALONS) System, mounted in a 15-inch diameter pod, is being tested and flight data analyzed to determine the radar's capability to operate in adverse environments and provide multimode radar data in support of tactical missions. The TALONS radar interleaved modes include:

(a) Terrain Following/Terrain Avoidance
(b) High Resolution Ground Map
(c) Fixed/Moving Target Detection/Track
(d) Fixed Target Enhancement

In the battlefield scenario limited sensor visibility due to cloud cover, adverse weather, night, smoke, fog and dust reduces the effectiveness of close air support and interdiction aircraft. The TALONS system, operating at 95 GHz, offers the operational visibility of the lower frequencies while providing real-time high resolution radar data resulting in precise weapon delivery and gun firing commands. Additionally, the radar will provide the capability to terrain-avoid, and terrain-follow including "blind letdown" thereby greatly enhancing survivability for tactical aircraft.

To substantiate this capability and to establish the 95 GHz sensor's tactical operational utility a flight test program has been undertaken. The overall objective of the TALONS flight feasibility demonstration is to collect sufficient data for meaningful assessment and provide the basis for further development. The flight test is being structured to demonstrate the above modal capabilities in adverse environments, under controlled tactical sitations.

2. Tactical Mission Scenario Requirements - Figure 1 illustrates a typical attack scenario. Blind letdown occurs at a safe distance from enemy locations and at ranges beyond 15 km. Low level terrain avoidance/terrain following penetration to the target area is required. Detection of targets begins at the 10 km range, terrain and weather permitting. Target tracking begins at the 5 km range with weapon deliveries beginning at 3 km.

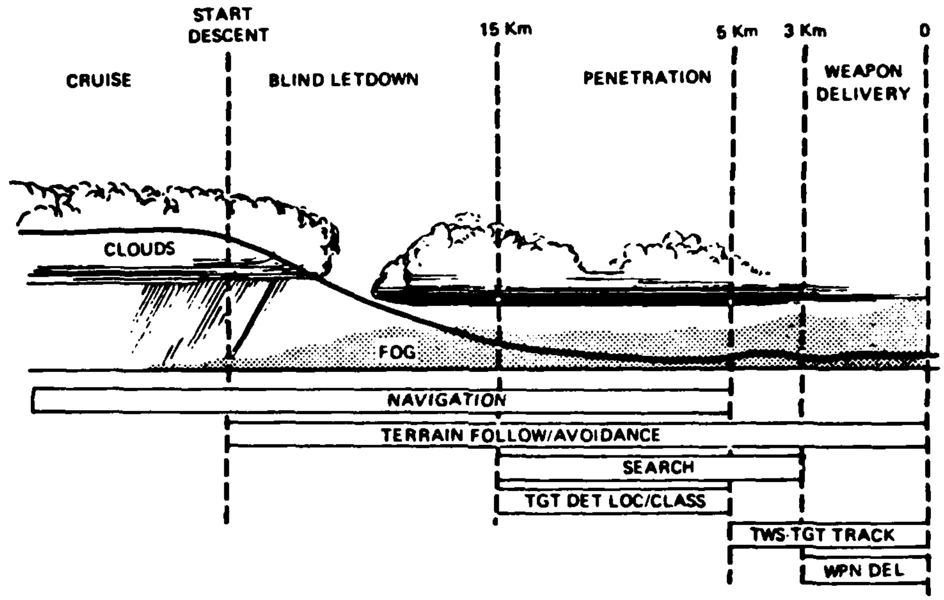


Figure 1. TALONS Attack Profile/Radar Functions

3. <u>*Millimeter Wavelength Solution*</u> - *Norden Systems* reviewed several of the MM wavelengths that have atmospheric windows such as 95, 140, and 220 GHz. The 95 GHz was chosen as the MM wavelength that can provide the performance needed for the airborne tactical mission. MMW components are developing rapidly with increasing performance and reliability, and the 95 GHz components have received considerable interest in recent years. The Army's 95 GHz RPV radar developed by Norden Systems provided the basis for the design of the TALONS system and the performance predictions have been analyzed using the RPV data base.

The 95 GHz solution uses advanced components such as the new Varian extended Interaction Oscillator (EIO) transmitter and a low loss integrated receiver package to provide the range performance compatible with the tactical scenario. The small size of the 95 GHz components make it very adaptable to small pod configuration and yet achieves both high gain and narrow beam widths. Reference 1 indicates that both the 95 and 140 GHz wavelengths are basically unaffected by smoke and dust especially when compared to their effect on the visible or long IR wavelengths. Fog and moderate rain causes mild attenuation compared to the lower microwave frequencies; however, the losses are tolerable particularly considering the short ranges expected when operating at low level ($\sim$60 meters) in moderate rough terrain where terrain will mask visibility to under 5 km for most of the flight.

Operation of 95 GHz provides good ECM immunity due to the narrow agile beam coupled with the expected atmosphere attenuations. Also at the present time, jammers at this frequency are not known to exist in operational equipment.

The small beam widths provided by a 95 GHz radar results in accurate target tracking and provides increased target to clutter ratios as well as high resolution ground maps which will be needed for navigation update. Tank tracks and road beds should be detectable, and aid in location of suspected enemy activity as well as aid in navigation.

The 95 GHz radar solution is compatible with the relatively short ranges required for TA/TF over moderate terrain in responsive tactical aircraft. The moderate terrain model (Fulda Gap) is well characterized by the southern Pennsylvania 6201 terrain used in TF simulations for design verification.

In summary, a 95 GHz solution appears to have many desirable features that should enhance the short range tactical close air support mission and the purpose of the TALONS program is to verify the features in realistically simulated tactical scenarios.

4. Modes of Operation - The millimeter radar will provide and demonstrate the following modes of operation:

(a) Manual Terrain Following (MTF)
(b) Manual Terrain Avoidance (MTA)
(c) Moving Target Indication (MTI)
(d) Fixed Target Enhancement (FTE)
(e) Ground Map (GM)
(f) Target Tracking - Fixed and Moving (FTT/MTT)

The radar modes operate simultaneously with only the MTI, FTE, and GM requiring operator selection. For example, MTF, MTA, GM, MTI and Target Tracking are provided simultaneously. Target tracking of fixed or moving targets uses track-while-scan techniques in order to be available simultaneous with the other modes.

5. Radar Description - Figure 2 provides a block diagram of the 95 GHz TALONS flight test radar. For ease of evaluation only the critical RF units will be mounted in the pod. The data processing, interface units, controls, and tape recorders will be located in the aft compartment of the test aircraft providing convenient access to test points. This will aid in monitoring the radar performance and facilitate rapid troubleshooting of the equipment.

6. Radar Parameters - The significant radar parameters are summarized in Table 1. The radar has the capability to operate in two modes which include a short pulse (80 ns) and a long pulse (400 ns). The short pulse provides a high resolution ground map (HRGM) with fixed target enhancement (FTE) and hard target

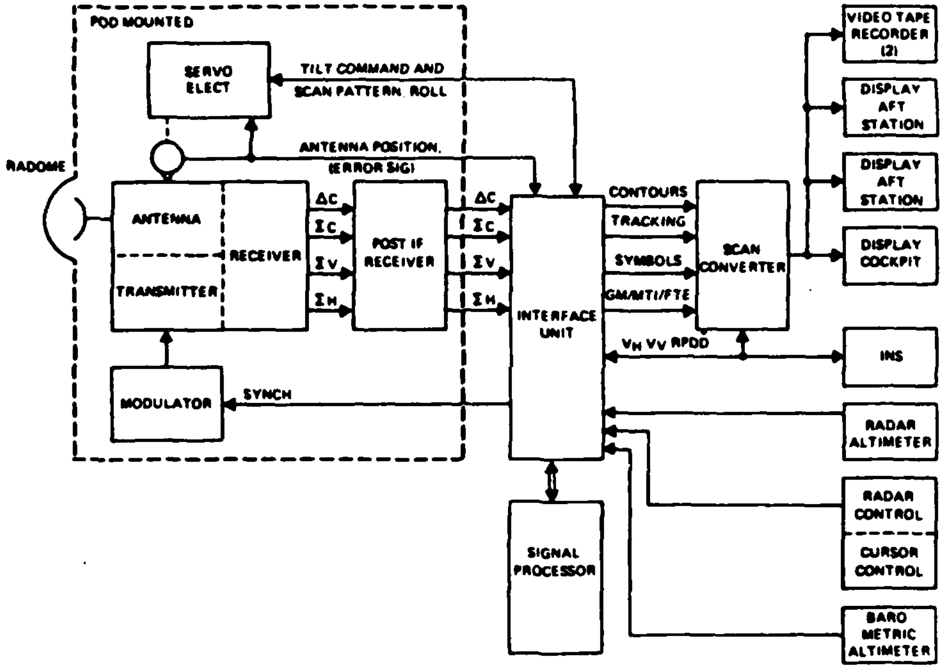


Figure 2. TALONS Flight Test Radar Block Diagram

FREQUENCY	95 GHz		
ANTENNA			
APERTURE (INCHES)	12 x 9.0		
BEAMWIDTHS (DEGREES)	0.8 x 1.0		
PEAK POWER (KW)	2.0		
	MODE 1		MODE 2
	MTI	GM	HRGM
	MTT	HTT	HTT
	TF/TA	FTE	FTE
AVERAGE POWER (WATTS)	5.0		1.2
PULSE WIDTH (nSEC)	400		80
REPETITION RATE (kHz)	6.25		7.5

Table 1. Radar Parameters

tracking (HTT). The long pulse insures adequate clutter return for TA/TF, MTI and moving target track (MTT) modes.

7. <u>Flight Test Program</u> - The MMR Pod was mounted and flown on a Sabreliner (T39) aircraft. Figure 3 provides a conceptual layout of the pod mounted to the A/C fuselage and internal equipments. The pod contains the following radar components:

(a) Radome
(b) Antenna Transmitter Receiver (ATR)
(c) Receiver Post IF Amplifier
(d) Servo Electronics Unit
(e) Modulator

A 28-channel digital recorder was installed to record the intensity and phase of the return in each range cell. Playback and target signature analysis will be performed in ground computer facilities.

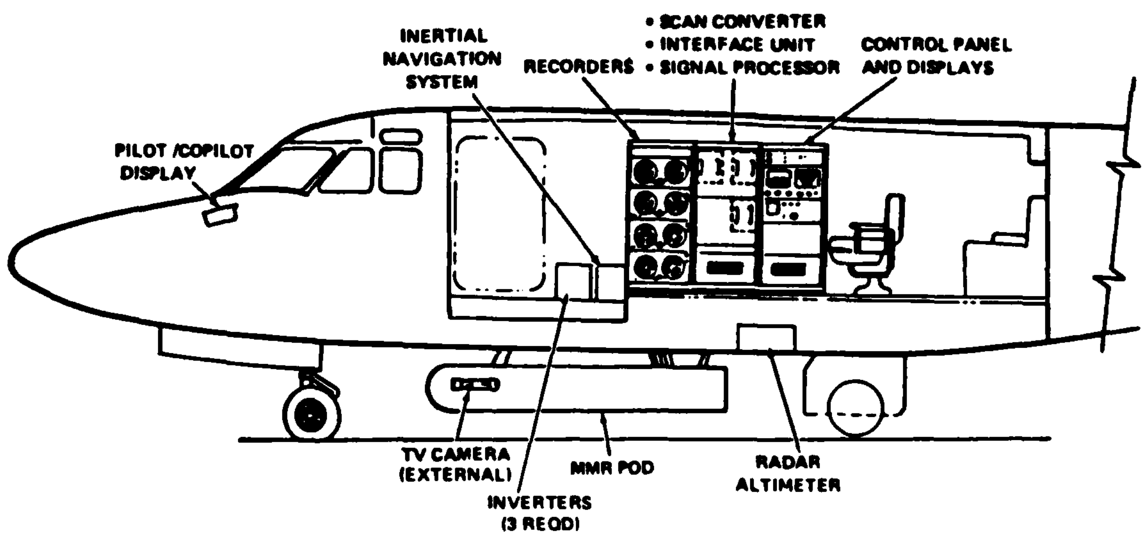


Figure 3. T-39 Aircraft - TALONS Flight Test Installation

Airborne data has been collected and recorded for ERADCOM, DARPA, and the Navy Research Laboratories during the flight test program. This data consists of:

Circular Polarization Backscatter Data;
Non-Coherent Doppler Returns; and
Elevation Monopulse Returns

8. Preliminary Results - The system has shown excellent stability and reliability in the RF components processor software and data recording equipment. A comparison of predicted and measured ranges shows that the detection of cultural targets exceeded expectations, while clutter detection predictions were optimistic. The test results are shown in Table 2.

WEATHER	TARGET	RANGE - KM	
		PREDICTED	MEASURED
CLEAN AIR	AIRPORT	11.0	17.0
	TANKS	7.0	7.5
	HILLY TERRAIN	16.0	11.0
	LEVEL TERRAIN	10.6	9.0
1 mm/hr RAIN	AIRPORT	9.5	10.0
	LEVEL TERRAIN	9.0	7.5

Table 2. Flight Test Results

9. Conclusion - The flight test program has successfully demonstrated the feasibility of a 95 GHz radar sensor for fighter aircraft avionics. In addition, a full circular polarization matrix data base has been obtained which will be explored for target classification and clutter discrimination.

10. Acknowledgement - The work described in this paper has been performed under Contract Number DAAK-20-81-C-0138. The authors wish to acknowledge the efforts of F. Rego, Norden project manager, K. Koester, Norden project engineer, K. Benson of Pratt & Whitney, and R. Kayuha and R. Benitez, Air Force program manager.

11. Reference

1. Kosowsky, L.H., et al "A Millimeter Wave Radar for the Mini-RPV" presented at the AIAA/DARPA Conference on Smart Sensors, November 1978.

How to Determine Avionics System "Affordability:

Dr. John G. Barmby, U.S. General Accounting Office
Washington, D.C.

Methods for estimating avionics black box costs are noted. Installation cost estimates are more difficult and life cycle cost estimates, covering software, test equipment, spares, and maintenance, are even more complex. Affordability also depends upon CFE versus GFE and contracting procedures. Cost effectiveness, considering combat utility, needs to be emphasized.

Pave Pillar: An Integrated Architecture for Affordable Flexible Avionics Systems

Capt. Daniel Quaderer, USAF, AFWAL/Avionics Lab.
Wright-Patterson AFB, OH

The Pave Pillar Program responds to the avionics problem and the fact that early subsystem integration promises improved avionics. Pave Pillar's objective is to develop and demonstrate the next generation integrated avionics system architecture. This architecture will significantly improve war-fighting sustainability, will reduce avionics ownership costs, and will enable combat mission effectiveness enhancements.

Maneuvering Weapon Delivery Performance Using Synthetic Aperture Radar

R. Bryan, USAF AFWAL/AART-3
Wright-Patterson AFB, OH

BACKGROUND

Two major challenges facing fire control design for tactical strike aircraft are in-weather targeting and pilot workload. These two issues become coupled when a significant portion of the pilot's workload is the manual recognition, classification, and designation of targets from an in-weather targeting sensor display. One approach to alleviate this workload is to automate some or all portions of this task, while the pilot continues to fly the aircraft in the weapon delivery approach profile. Another complementary approach is to reduce the pilot's flying workload, especially any precision manual control tasks which require a high degree of concentrated attention. This approach has been successfully developed and demonstrated under the joint IFFC I/FIREFLY III (Integrated Flight/Fire Control) flight test program, albeit using conventional clear-weather targeting methods. In addition to reducing pilot workload, the maneuvering weapon delivery approach also generates significant aircraft motion across the line-of-sight (LOS) to target, which happens to be a requirement of Synthetic Aperture Radar (SAR) to achieve fine scene resolution.

While these facts motivate a fire control system combining a SAR with the maneuvering profiles generated by IFFC, there remain a number of technical issues to be investigated to determine feasibility of such a combination. In particular, weapon delivery accuracy must be adequate for the target/weapon combinations of interest, while maintaining survivability at least as good as the clear-weather IFFC demonstration. In order to analyze the design factors affecting performance, it is desirable to determine sensitivities of the performance measures to the design factors, as well as to other factors, such as relative geometry and operating modes.

The Manuevering Attack Concepts Evaluation Program, Phase I (MACE I), is an in-house Exploratory Development program within the Applications Branch, whose purpose is to investigate the previously discussed issues as well as the application of this technology to multiple target attack. The paper presents the analysis methodology, four radar operating modes, test case conditions, and results of the investigation of maneuvering SAR weapon delivery. The investigation was performed using a detailed non-rea -time Monte-Carlo analysis computer program, which was modified under MACE I to perform this specific task. Results include weapon delivery accuracy as a function of radar parameters and geometry. The simulation itself was an improved and extended version of the Advanced FIREFLY Assessment (AFFA) Simulation and Analysis Program.

APPROACH

In general, the first step was to review and evaluate the AFFA simulation models. Where deficiencies were found, requirements, error sources and the specific modeling approaches were defined. In the case of radar models, this included defining the radar modes to be modeled. Each model was then developed or the AFFA model modified. The model was then evaluated, incorporated into the overall simulation, and a system test conducted. For each radar mode, analysis to determine the error sensitivity of specific parameters was conducted. The expected value of each critical parameter was determined and a point design performance analysis conducted. The final step was defining the baseline mechanizations.

RADAR MODES

Four radar modes were defined, modeled, and evaluated. Modes 1, 2, and 4 are coordinate bombing modes using the radar data to designate the target position and the Inertial Navigation System (INS) to propagate the aircraft to target position measurement during the bombing run. In all of these modes, a map of the target area is made using an aircraft pop-up maneuver to obtain a clear line of sight to the target area. This radar map data, along with the INS-measured aircraft position and velocity at map time, is stored. As the flight continues, an operator will view the radar map and designate the target position. This position, along with the INS-measured aircraft position at the time of target designation and the INS-measured position at map time, is used to compute the target position in the INS coordinate frame. The differences in Modes 1, 2 and 4 are primarily the differences in assumed radar capabilities and mode of operation.

Mode 1, the simplest radar, is assumed to have or use only the SAR mapping data. In other words, it does not use monopulse data. The SAR mapping data is in a range and Doppler frequency coordinate system. When a position on the radar map is designated, the designated Doppler frequency and the aircraft velocity are used to compute the azimuth squint angle (angle between the velocity vector and the designated position). This data, along with the designated range, is used to compute the target horizontal position in the INS coordinate system. Since there are errors in the aircraft velocity measurement, there are corresponding errors in the designated squint angle and the horizontal position. In addition, there are no radar measurements of target elevation. Therefore, the aircraft altitude is used to determine the INS target vertical position.

In Mode 2 it is assumed that the sum, azimuth monopulse, and elevation monopulse data are stored when the radar map is collected. When a position on the radar map is designated, the azimuth and elevation angles to the designated range and Doppler cell are computed using the stored monopulse data.

Mode 4 also uses monopulse data. The horizontal target position is found in the same way that is used in Mode 1. A few seconds before bomb release, the radar is activated and an elevation monopulse measurement is made to determine the elevation angle for which measured range equals computed target range. Therefore, a radar measurement of the designated target is accomplished. In addition, since the radar for this mode has monopulse capabilities, a radar velocity update can be accomplished prior to the mapping time. Therefore, the measured horizontal position can be better than that achievable with a standard Mode 1 measurement.

In Mode 3, target monopulse range and angle tracking is used for a time period just before bomb release. The target is initially designated as it was in Mode 1. Prior to initiation of target tracking, the target range and Doppler frequency are computed using the designated target position and current aircraft position and velocity from the INS. The radar searchs about the computed target range and Doppler and locks on and tracks (in range, azimuth, and elevation) the target. These radar measurements are processed through a Kalman filter to produce the estimated target position used by the fire control system.

RESULTS

A Monte-Carlo procedure using 21 runs (one an essentially no-noise run and 20 noise runs) was used in conducting the sensitivity and performance analysis. For each radar mode, a baseline configuration was established and evaluated. Additional test cases generated by changing one value at a time were also evaluated. For each test case, specific true and measured positions and velocities, and times at critical events (map, release, impact, etc.) were stored for each Monte-Carlo run. Using this stored data, specific error vectors were computed. Statistics (mean, standard deviations, minimum, maximum, median, CEP, etc.) were then computed for each error vector.

Radar Mode 1 is a coordinate bombing mode that uses SAR map data only, i.e., it does not use radar monopulse data. The variables that show the largest sensitivity are altitude error, velocity error, squint angle at map, and release range, in order of decreasing sensitivity. Radar Mode 2 is a coordinate bombing mode that uses monopulse data gathered at the time the radar map data is collected to measure the range, azimuth angle, and elevation angle to the point that is designated at the target position. The results show that Mode 2 is more accurate than Mode 1, and that the measured and estimated positions are less correlated (more random). The miss is now sensitive to some of the monopulse angle error sources (radome, boresight, clutter, radar cross section, and integrated sidelobe ratio) as well as horizontal velocity, squint angle and aircraft speed.

Radar Mode 4 is a coordinate bombing mode where the target horizontal positions are determined as in Mode 1. However, a few seconds before release, an elevation only monopulse measurement is made to determine the elevation angle to the terrain that is at the expected target range. A comparison of results shows that Mode 4 is substantially better than Mode 1. The measured target positions exhibit the same correlation that is related to the cross range direction at map time, but that the magnitude of the error is less. This is caused by the fact that a baseline 1.0 ft/sec horizontal velocity error was assumed instead of the 1.5 ft/sec that was assumed for Mode 1. This reduction in baseline velocity error was assumed because the Mode 4 radar has a monopulse capability and therefore should be able to perform a precision velocity update prior to making a map. The larger miss distance sensitivities occur for the horizontal velocity error, squint angle, and depression angle. The depression angle sensitivity is caused by the fact that the measured elevation angle at update is used to compute the altitude of the aircraft with respect to the target using the measured INS vertical.

In Mode 3 the target position is initially designated as it was for Mode 1. However, prior to bomb release the radar acquires the target and tracks it in range, azimuth, and elevation. This mode was evaluated for both stationary and moving targets. The evaluation for stationary targets has been designated as Mode 3S and for the moving targets 3M. The evaluation for stationary targets will be the only one discussed. The most sensitive parameter is track time. It is felt that the sensitivity to track time is being driven by the number of measurements that are processed by the target state estimator Kalman filter. The main effect of horizontal velocity error is in the ballistic prediction error.

The MACE radar Mode 1 sensitivity analysis highlighted the weapon delivery accuracy dependence on INS performance, motivating one additional performance data point. With better inertial information (ownship velocity and altitude), a weapon can be more accurately delivered against the designated target. Therefore, a more accurate inertial system was simulated to determine the weapon delivery accuracy. Very accurate ownship data can be obtained when using Global Positioning System (GPS) information. The MACE INS model's input errors were changed to simulate ownship data of a GPS-type quality. When GPS-type errors were used, weapon delivery accuracy was greatly improved. These results are largely due to the fact the target is assumed to be in the same ground plane. Therefore, the aircraft's absolute altitude and the relative altitude between the aircraft and the target are the same. If the target and aircraft ground plane are not the same, the GPS-provided aircraft altitude could not provide the necessary relative aircraft altitude. This is because target altitude cannot be provided by GPS. This error between the relative and absolute altitudes would translate into a weapon delivery error in the same manner it did in Mode 1.

CONCLUSIONS

The Mode 2 radar would require storage of sum, azimuth difference, and elevation difference data when the radar map is gathered. The other modes would require only sum data. Because of this additional data storage requirement and the fact that Modes 3S and 4 give better results, it is recommended that Mode 2 not be considered further. The Mode 1 results indicate that adequate accuracy cannot be achieved unless very good externally provided (e.g., with GPS) aircraft altitude and velocity data, and good target altitude data, not provided by GPS, are available. It should be noted that Modes 3 and 4 inherently have Mode 1 included. Therefore, Mode 1 would be available as a backup or fall-back mode if Mode 3 or 4 is implemented. Mode 3S provides the best accuracy. However, some period of dedicated tracking time is required. Mode 4 provides reasonable accuracy and requires less dedicated radar time just prior to release.

New Technology Defensive Avionics

E.J. Dryer, Rockwell International

INTRODUCTION

Defensive avionics being conceived for the next generation aircraft will provide unique improvements over current avionics capabilities. These new concepts will utilize current technology breakthroughs to assure electronic superiority over the projected threat environment throughout the operational life of the new aircraft. For the first time, the countermeasures employed will be adaptive in nature and surgical in response to each attack mode of each threat. These bold statements can be attributed to both advances in electronic technology and advances in reducing an aircraft's radar cross-section. The previously unachievable countermeasure capability emanated from the development of many aspects of avionics technology, each synergistically complementing the other. Further, advances in electronic component technology have driven size, weight and power parameters into compatible submission to the basic constraints of a high performance, low radar cross-section aircraft.

The core of the next generation aircraft's defensive functions lies in the threat sensor processing subsystems capability to accept and correlate relevant inputs from any of the various sensors available to the aircraft. High speed processing of the combined sensor data will provide the defensive system with the data required to control on-board off-board, and supportive countermeasures.

A priority data file, often called the threat or alarm file, will be maintained for identifying each threat. Further, the system will be programmed to track the sequence of events (acquisition, lock-on, track, missile launch) that lead to an attack. Knowing the phase of the attack operation will permit the use of optimized countermeasures during each sequence of the attack events.

The active electronic countermeasures (ECM) segment of the defensive avionics will utilize a multitude of ECM techniques. (In order to ensure effectivity, the stored ECM techniques will be reviewed continously and changed as a function of threat susceptibility analysis.) When a threat radar is to be jammed, a generic countermeasure (which may be a combination of ECM techniques) will be selected which has been determined to have the best capability to exploit that particular threat's ECM susceptibility at that particular event time. As the threat sequences through various phases of its attack mode its vulnerability to specific ECM techniques will also change. The surveillance segment of the defensive avionics will provide both the threat's mode of attack and a measure of ECM technique effectiveness. If a selected countermeasure were found not effective

against a particular threat, then the defensive avionics would have the capability to find a saddle point solution to a Max-Min game of countermeasure vs. counter-countermeasure for that segment of the attack. The ECM strategies associated with each of the various missions would utilize a cooperative exchange of data in a master/slave relationship for each element of the raid.

THE THREAT

Today's threat to U.S. Military aircraft which penetrate Soviet airspace, has been described as awesome. Two of the significant factors contributing to the awesome descriptor is the dense threat population and the diversity of electronic characteristics exhibited by the total threat. It should be noted, however, that the Soviet's newest and most respected SAM (the SA-10) will be over twenty years old by the year 2000. It is a certainty, considering the current electronics technology growth in the Soviet Union, that the threats to the next generation aircraft will possess greater sensing and computational capabilities than the SA-10.

THE AIR FRAME

The airframe and avionics concepts of the next generation aircraft each impact the others' design. The low radar cross section of the basic airframe impacts the defensive avionics in several ways. First, the radar cross section of any antennas or apertures must not significantly change the aircraft's overall cross section. Second, the required effective radiated power for ECM radiations may be reduced 20 to 30 dB from current requirements due to the lower radar cross section. Third, silent running and stealth are expected to significantly change the lethal threat encounters. This forces a stronger reliance on passive sensors or low probability of intercept sensors and places more importance on the threat's time available for attack.

DEFENSIVE AVIONICS

In order to accrue the advantages of silent running with stealth, the next generation aircraft should be capable of utilizing all of the available information pertaining to the immediate threats. The aircraft sensors together with pertinent off board sensors will be a source of data during a mission. Individually, the sensor data may be of little value. Combined, the sensor data may identify an immediate threat. Combining sensor data will be an integral part of the future aircraft's avionics. The process begins with all of the individual sensors, each of which has been becoming progressively more effective with each new development. The system would be capable of fusing an array of low level sensor observations (samples in space and time) into some type of replica correlation to make a positive identification of a threat.

ARTIFICIAL INTELLIGENCE

If the next generation aircraft is to achieve electronic superiority over the enemy, the avionics system will be forced to utilize computers to make critical decisions, i.e., Artificial Intelligence (AI). Because of the speed required to counter some threats, this use of AI will force a shift from the central general purpose computer to the concept of many local embedded special purpose micro-computers. Studies in computer architecture which are aimed at developing highly parallel systems incorporating multiple special purpose microprocessors coupled to a massive main memory are in progress.

COOPERATIVE TACTICS

Advances in electronic technology for the next generation aircraft will support a wide variety of cooperative tactics. Avionics systems, originally designed as autonomous, can achieve synergistic force multiplier effects by intelligent information processing with other weapon or sensor systems. Multiple aircraft missions and multiple target engagements on the same raid in a severe threat environment are predicted for present and future military missions. Coordinated attacks may play a decisive role in attaining superiority in both air-to-air combat and air-to-surface operations. Processing pertinent data from other platforms can provide information: to better select a threat countermeasure; or to provide a capability to assess threat situations before time becomes a critical factor; or to provide precise flight path control for a maneuvering attack on a highly defended target; or to provide priority target assignments plus steering in a multiple aircraft, multiple target situation. The next generation aircraft will be capable of the utilization of cooperative tactics and the utilization of data from a multiplicity of information sources. The utilization of artificial intelligence and cooperative tactics will bring a new level of man-machine relationship.

SUMMARY

Technology advances in electronics and stealth have provided the United States with an opportunity to regain a multi-year lead in the electronic superiority race with Russia. The development of VHSIC and LSI circuits, for example, will provide the next generation aircraft with a computing capability that will not limit sensor performance or reaction time. New excellence in sensor capability, avionics system performance and future computer architecture can provide the next generation aircraft with electronic superiority.

InMASS: An Integrated Multiple Aircraft Surface Strike Fighter Concept

H.R. Melton, Director, Tactical Systems
SPARTA Incorporated, Laguna Hills, CA 92653

This paper deals with an Integrated Multiple Aircraft Surface Strike (InMASS) fighter aircraft concept that derives its cost effectiveness from extensive use of data processing and cooperative tactics among several aircraft using relatively unintelligent if not dumb weapons. This concept is one of several that evolved from work that was reported by the author at the 43rd Military Operations Research Society (MORS) Symposium in July 1979 ("Swarm Fighter: The Next Generation Tactical Fighter"). This concept is termed InMASS and approaches the solution of the tactical problems using technologies currently under development in a combination that has not been addressed yet. Although most of the ideas are not new they have not been technically feasible even in the most recent past. It is felt that technology has progressed such that this combination should now receive sufficient attention to determine its feasibility.

Figure 1 illustrates a portion of the FEBA upon which the Soviets have decided to concentrate their forces. Sketched on the map are the armored regiments and the ground to air defenses in the area.

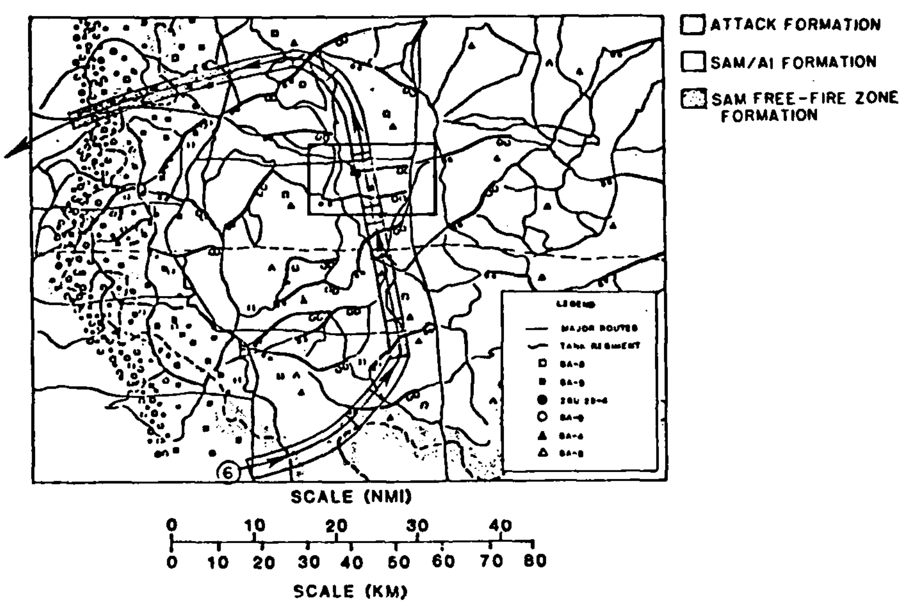
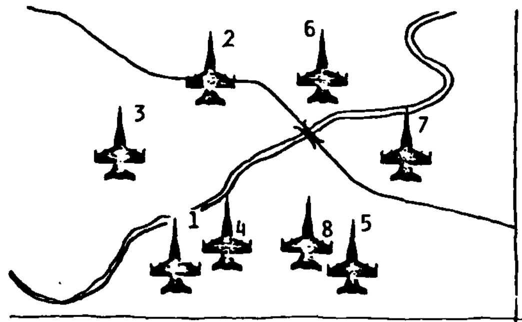


Figure 1. Air Interdiction Problem in Perspective

In Figure 1 is illustrated a flight path for an InMASS group and shows that there are several environments that the group of aircraft would pass through that would require different tactics to be used by a group commander. In his early penetration, he knows from intelligence data that he will be entering an area where he will be encountering both ground defenses and Airborne Interceptors (AI). This information will influence the way he distributes functional assignments within the group as well as the way he flies his group. As he approaches a known target area he will want to rearrange his group into an attack formation. Once he has exited the target area he will perhaps return to the previous formation. Upon approaching the FEBA he anticipates that he will be required to fly through an intense ground defense region where the defenses have been given the authorization to fire at anything flying. In this region his possibility of encountering an AI is much reduced. He might therefore decide to maximize his survivability against ground defenses by reorganizing his group.

Figure 2 illustrates a seven aircraft group penetrating a SAM free fire zone as discussed previously. The group is closely spaced (limited by safety considerations) to keep them within the beam width of a typical threat radar at a certain range. The aircraft are flown by the system in a station-keeping mode and positioned to maximize their effectiveness for their particular assignment. The table on the upper right of the figure describes the functional assignments of the onboard systems and the pilots. Thinking of the pilots as crew members of the group (a seven man crew) rather than pilots of their individual aircraft is a helpful perspective. Since we are concerned with intense ground defenses we have assigned three crew members the Electronic Warfare (EW) functional assignment. These three members of the crew have the threat world divided among them either by frequency, threat type, or perhaps attack azimuth. Their displays are configured to maximize their effectiveness in their <u>one</u> assignment, the EW function. In the process of performing his duties he may decide to launch (or approve the launch of) an ARM missile, which system may launch from another aircraft. The crewman and the systems on his aircraft are decoupled. He is working as part of an interdisciplinary team. His aircraft resources are part of the total resources of the larger group system. He is a crewman of the group system in the true sense of the term. In the figure the ECM systems on aircraft 2,3,6 and 7 have been selected by the system to operate in a cooperative jamming mode. This is done automatically by the system under the direction of the three EW team members. Two other crew members are given the function of TF/TA and navigation. Their displays are configured for their dedicated function. Since we do not expect to encounter AI's we only use one of our crew in that function. Two of the crew are designated as flight leader and deputy flight leader and work together on the command/control function. Their controls and displays are configured to provide them the information required by them to make the tactical decisions for the



	SENSOR ASSIGNMENTS			CREW MEMBER
	RADAR	RWR	ECM	ASSIGNMENT
1	-	-	-	TF/TA
2	TF/TA	ON	COOP	EW1
3	AI	-	COOP	FLIGHT LEADER
4	-	ON	-	EW2
5	-	-	-	TF/TA
6	TF/TA	ON	COOP	EW3
7	AI	-	COOP	DEPUTY FLIGHT LEADER
8	-	ON	-	AI SEARCH

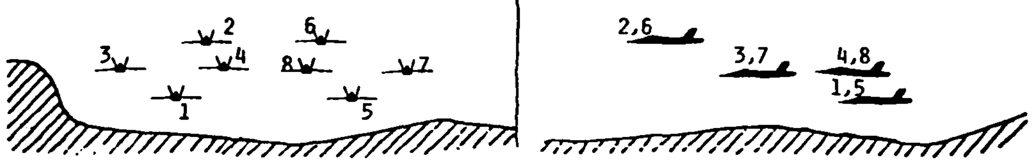


Figure 2. Penetration Formation for SAM
Free Fire Zone

group. The deputy actively participates in the decision making process and is ready to step in, if and when he is needed by incapacitation of the Flight Leader.

Figure 3 illustrates some of the Flight Leader's parameters of control of the system. These are tactics that have been developed by the crew previously either in training or as the result of previous missions. Tactic "A" is an optimum cruise and corresponds to some of the 4-D Navigation work now under study. The Flight Leader works with the system in terms of the destination, crew functions along the way, any constraints he might want to impose on the system relating to intermediate conditions desired, etc. These parameters are controllable continually during the execution by the system to allow him the flexibility to relate the parameters to the continuing development of the tactical situation. He is functioning in a role that a man is best suited to, and is not being required to perform a function that a machine could do better. His adaptability and innovativeness is his contribution and the system is automated to implement his solution with the precision, repeatability and endurance that it does best.

Figure 4 illustrates how the functions might be distributed among the men during the attack phase of the mission. Each bar represents the optimum man/machine mix for that function. As can be seen in the figure, this particular partitioning of functions

TACTIC	TYPE	APPLICATION	PARAMETERS OF CONTROL
A	OPTIMUM CRUISE	TRANSITING NON-THREATENING AIRSPACE	DESTINATION, CREW FUNCTIONS, INTERMEDIATE (POINTS, ALTITUDE, FLIGHT PATH), SPACING, VELOCITY
B B1 B2 B3	LOW-ALTITUDE CLOSE MAXIMUM COVERTNESS NON-LETHAL COUNTERMEASURES ACTIVE/LETHAL DEFENSE	PENETRATING SAM FREE FIRE ZONE	GROUND CLEARANCE, VELOCITY, OVERALL FORMATION SPACING, AIRCRAFT/CREW FUNCTIONAL ASSIGNMENTS, PASSIVITY
C	LOW-ALTITUDE LOOSE	PENETRATING SAM/AI MIXED ZONE	SAME AS ABOVE
D	ATTACK FORMATION 1	DENSE TERMINAL DEFENSES	SAME AS ABOVE, PLUS TARGET PRIORITY
E	ATTACK FORMATION 2	LIGHT TERMINAL DEFENSES	SAME AS ABOVE, PLUS TARGET PRIORITY
⋮	⋮	⋮	⋮

Figure 3. Examples of Tactics Available to Flight Commander

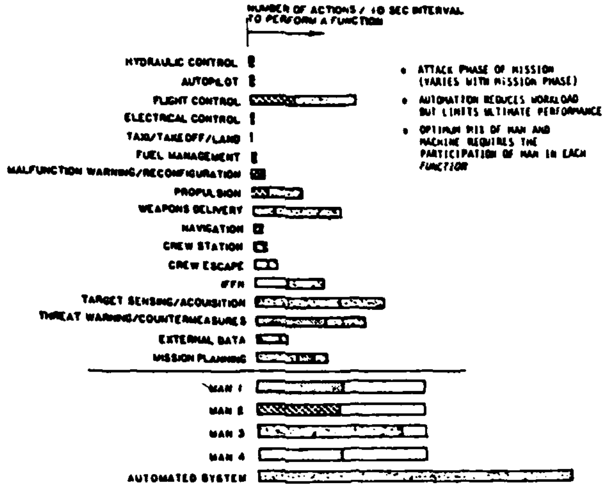


Figure 4. InMASS Distributes Functions Among Men

is arranged so that none of the crew is fully loaded. In each case the relative positions of the aircraft, the assignments of the pilots and the system resource allocations have been changed to maximize the effectiveness of the group under the control of the crew.

As is illustrated in Figure 5 the aircraft fly in a random formation, but grouped such that the lead aircraft sensor system sweep volume covers the spread of the trailing aircraft. Also illustrated in Figure 5 is the attack on a single target by several aircraft. The weapon to be used in this concept is an off-axis ballistic round of some sort. This weapon is not a high fire rate cannon but a single shot weapon. Reload may be a

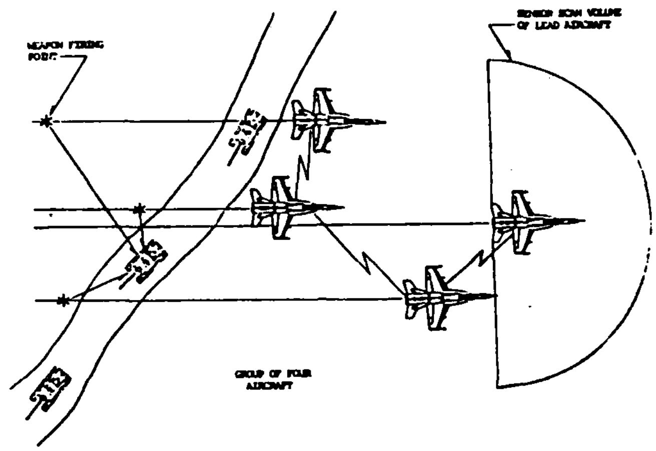


Figure 5. Planform View of InMASS Attack

requirement for the multi-shot capability but the reload rate is on the order of a second or so. The weapon can be pointed either by an aircraft maneuver or by training the weapon.

A preliminary analysis was conducted including the following effects:

(1) Moving targets (20 fps in random directions),

(2) Fraction of false targets (2),

(3) Spacing in trail (1200 ft),

(4) Aircraft velocity (800 fps),

(5) Pk data 10 Milliradian for weapon delivery accuracy,

(6) Detection sensor location error (3 ft),

(7) INS drift error (2.5 ft/sec),

(8) Number of weapons per shot (4),

(9) Vulnerability area (328 sq ft), and

(10) Velocity measurement at the addition of data from Aircraft 2 with the associated error (0.25 ft/sec)

(11) 8 aircraft in swarm,

(12) 12 swarms,

(13) Swarm front 0.6 NM wide,

(14) Number of targets attacked per aircraft is 3,

(15) Two sorties prior to returning to base (refueling over friendly space is assumed),

(16) Three basings per day per swarm.

The results are represented by the point in Figure 6. The days required to achieve the objective was 1.0 day. Each aircraft has a different probability of kill, P_{kss}, depending upon the INS errors building and the addition of a velocity measurement by the second aircraft and used for the third and fourth aircraft. The targets are attacked during a fly over and all three trailing aircraft take a shot at them.

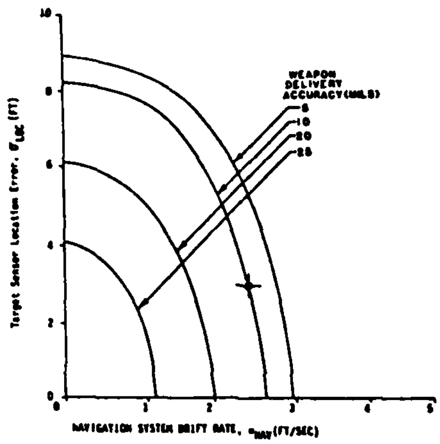


Figure 6. System Error Trades

Figure 6 also presents the sensitivity of the results to the three major error sources used in the analysis. The baseline case is indicated by the centroid symbol. The Navigation System Drift Rate, the Target Sensor Location Error, and the Weapon Delivery Accuracy are traded while maintaining the days to reach kill criteria at one day. Any point within these curves will result in the days to reach kill criteria being less than one.

The preceeding discussions have demonstrated that there is a potential of a new approach to the Tactical air-to-ground mission that, if incorporated in our inventory, would significantly increase the effectiveness of our Tactical forces. It is felt that the potential advantages of such a concept are:

(1) It involves conventional Weaponry (non-nuclear),

(2) It would mean fielding a system not readily matched by the Soviets,

(3) The system is robust to non-performance of automatic target recognition (ATR) while at the same time offering an operating environment that promises dramatic improvements in ATR,

(4) System survivability to dense threat environments (e.g., in European theatre conflicts) is high,

(5) The system shows promise for functioning well in protracted conflicts,

(6) The system is inherently covert,

(7) The system provides high quality real time reconnaissance data,

(8) The system is group-autonomous and therefore robust relative to loss of support systems,

(9) Allows crew to work with system in terms of tactical parameters rather than equipment directives thereby maximizing crew effectiveness,

(10) All technologies required are within the state of the art,

(11) Equipments on the aircraft can be used to increase overall system reliability through resource allocation and redundancy beyond that available with any single aircraft, and

(12) It provides the potential of cost savings when the system is optimized to derive maximum advantage of its internetted aspects.

Foxhound Airborne Intercept Radar

H.V. Miller, USAF, Avionics Branch/FTD
WPAFB, Ohio

The estimated overall performance characteristics and capabilities of the airborne intercept radar for the Soviet Foxhound fighter will be presented.

Radar Technology for the 1990s

T.E. Harwell, Texas Instruments Incorporated
Dallas, Texas

INTRODUCTION

Technological innovations provide the basic building blocks needed for effective solutions to critical military operational problems. Texas Instruments (TI) is currently developing VHSIC components, advanced solid-state transmit/receive (T/R) modules, high-density power supplies, and advanced receiver/exciter and processor architectures that will mature in the mid-to-late 1980s. These emerging radar technologies promise the substantial advancements over contemporary radar designs that will be needed to satisfy the stringent multimode/multimission functional and availability requirements anticipated for airborne radar systems of the 1990s.

TI believes that solid-state active-element phased-array radar technology will become an operational reality in the late 1980s. We forecast the airborne radar market will experience a discontinuity during the coming decade even larger than that resulting from the development of coherent digital signal processing in the 1960s. This discontinuity will be a result of the development of cost-effective, active-element, phased-array technology, high-density, high-capability processing via VHSIC, and the necessary support technology. As illustrated in Figure 1, this discontinuity will essentially merge most previously distinct airborne radar mission/market segments into a single market with a common technology base, i.e., high reliability and true multifunction systems. This paper summarizes the primary development activities that will lead to radar technology for the 1990s.

TECHNOLOGY FORECASTS

Solid-State Transmit/Receive Module Technology - Solid-state T/R module technology for airborne radar applications has progressed significantly since the technology was first investigated in the 1960s. During the 1960s and 1970s, designers were limited by available technology, i.e., silicon microwave transistors. Silicon transistor technology required power to be generated at lower frequencies (S-band) and to sustain the loss of frequency multiplication to reach operating frequencies (X-band). In the early 1970s, it was determined that this was an impractical approach and direct X-band amplification on transmit and receive would be required for implementation of an affordable, usable high-frequency T/R module.

Advances in GaAs field effect transistors (FETs) since the mid-1970s now provide a technical base that supports the implementation of a solid-state phased-array radar that will match the

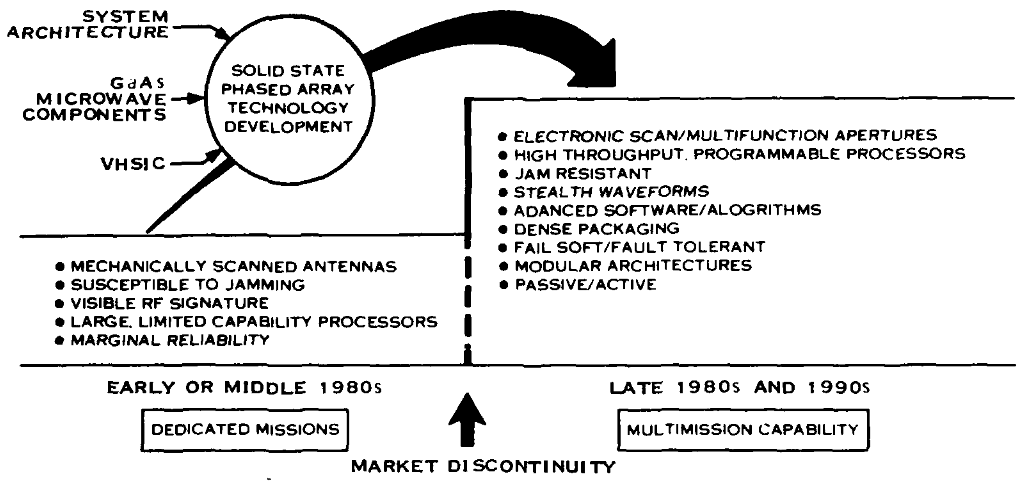


Figure 1. Cost-effective solid-state phased arrays will merge the radar market

performance of the most sophisticated, contemporary airborne fire control systems. Examples of today's technology are shown in Figures 2 and 3. Figure 2 is an X-band T/R module developed by TI for the Naval Research Laboratory (NRL). The module has a nominal peak power output of 4 watts (W) and achieves a bandwidth of over 1 gigahertz (GHz) in transmit and receive modes. Receive channel noise figure is typically 4.5 decibels (dB). Phase shifter performance will support the most stringent system sidelobe demands. Figure 3 is a derivation of the NRL module that was configured for an Air Force Wright Aeronautical Laboratories (AFWAL) aperture development program. The module has been designed for full compatibility with the military environment. Table 1 shows physical properties and interfaces for the AFWAL module.

During the coming decade, major advances in output power, efficiency, and noise figure are not anticipated. Instead, emphasis will focus on gradual improvements in these parameters and will stress other features such as precision gain control techniques and cost reductions. Monolithic circuit technology, dual-gate FET investigations, manufacturing technology, and packaging advances are examples of the thrusts of the 1980s. Significant increases in GaAs FET power output capabilities are not anticipated because of practical limitations on gate width, chip size, and thermal considerations. However, a caveat should be noted, based on the possibility of development of bipolar GaAs structures for microwave applications. Should this occur, practical peak power expectations could increase by a factor of 2 to 3. Table 2 characterizes the expected production parameters for X-band T/R modules of the late 1980s and early 1990s.

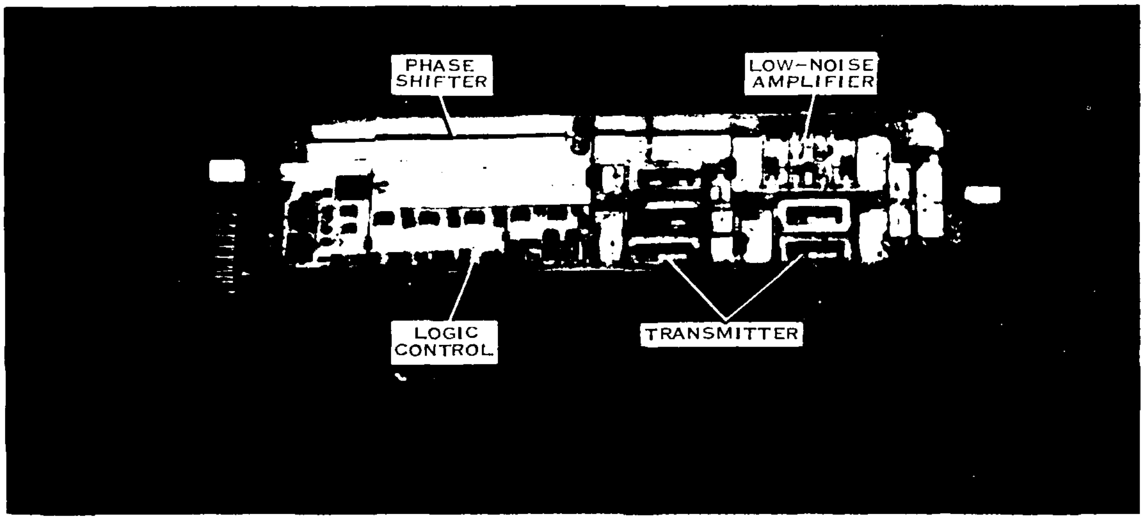


Figure 2. NRL module assembly

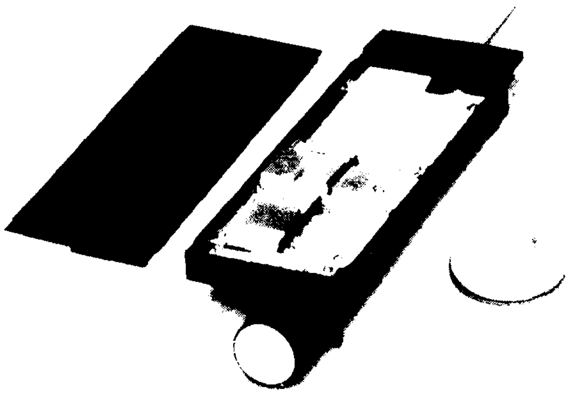


Figure 3. AFWAL module mockup

Table 1. AFWAL Module Characteristics

Module physical characteristics	
Length	4.05 inches 5.30 inches with element
Width	1.33 inches
Thickness	0.27 inch
Weight	1.73 ounces
Module interfaces	
Power	+6.5 volts +5 volts −5 volts
Control	T/R synchronization Data enable Data
Manifold	Transmit, 50 Ω coax Receive, 50 Ω coax
Antenna	Matched circular waveguide

Table 2. Production module parameters for the 1990s

Parameter	Range
Output power	To 10 watts peak for GaAs FET output devices
Operating bandwidth	20 to 50 percent
Module efficiency	To 25 percent at 50 percent duty
Noise figure	3 dB nominal
Module weight	1 to 1.2 ounces per element
MTBF	Greater than 100,000 hours

Digital Devices - The trend in performance levels of digital devices (integrated circuits and memory) for radar applications in the 1990s is truly phenomenal. The growth in performance is being driven by both the DoD VHSIC program and commercial computer development. By 1987, we will see a fivefold increase in speed and at least a fourfold decrease in size, weight and power with the introduction of VHSIC I [1.25-micrometer (m) technology] parts. Into the 1990s, VHSIC II (0.5- m technology) will produce comparable improvements. Furthermore, the VHSIC program will yield truly militarized parts with functional designs keyed to radar applications. Also, we will see the introduction of LSI parts with high electron mobility transistors (HEMTs) on silicon and mature gallium arsenide (GaAs) ICs. These technologies promise gate speeds less than 50 ps and memory-access times less than 5 ns. Solid-state process technologies using HEMT and GaAs ICs are forecasted to produce a performance increase of greater than tenfold over VHSIC II by the late 1990s.

Both volatile (RAM) and nonvolatile (PROM, magnetic bubble, etc.) memory devices are forecasted to quadruple in density every 4 years into the foreseeable future. VHSIC I parts (late 1980s and early 1990s) will feature 16K static RAMs both in CMOS and NMOS technologies. CMOS will eventually replace NMOS for static RAMs used in high-density, low-power applications. The 1990s

will see 1-megabit CMOS static RAMs with error correction capability. Access times for these high-density RAMs will be on the order of 25 ns. GaAs memory will become the high-speed leader. One manufacturer has reported a 1K static RAM using GaAs with an access time of 4 ns.

Nonvolatile memory will experience similar performance and density increases. The 1-megabit CMOS PROMs will have access times on the order of 25 ns and multimegabit magnetic bubble memories are likely to be common. One manufacturer has demonstrated a 4-megabit magnetic bubble memory. The UV EPROMs will show like improvements but will probably be replaced with electrical EPROMs with densities of 1 megabit by the late 1990s. One company has a 1-megabit mask ROM in production in 1983 and another company is introducing a 256K UV EPROM in 1983.

Data Rates/Interfaces/Fiber Optics - Recent progress reported in fiber optics communications points the way to high data rate aircraft systems in the 1990s. Data rates exceeding 2 gigabits/s have been reported in experimental fiber optics systems. Long-distance transmissions exceeding 5 km have been achieved routinely at these rates. Current fiber optical materials are immune to electromagnetic pulse (EMP) effects, but most fibers subjected to radiation do show varying detrimental effects. These effects are both transient and long term with respect to attenuation. Much progress is being made in overcoming the radiation problems and it is believed that radiation-hardened fibers will be available in the 1990s. If the current nuclear hardening problems can be overcome, the speed, noise immunity, size, and weight potential makes fiber optics a logical choice for future aircraft systems.

The high data rates (greater than 500 megabits/s) will be attained with the new bandgap laser diodes. Several investigators have reported laboratory experiments of self-clocking T/R systems in the 2-gigabits/s range. These systems used single mode fibers, which are becoming common-place even now.

Power Supplies - TI has been active in the research, design, and development of power supplies for military applications for many years. Our current internal research and development (IR&D) efforts in militarized, low-voltage switching power supply designs are directly applicable to solid-state phased-array radars and other advanced avionics equipments needed for future military applications such as the VFMX, ATF, and Pave Pillar. The main goals of this IR&D program are a high demonstrated reliability (a fivefold improvement in reliability over current power supplies in use); improved efficiency; and advanced, high-density packaging under full military specification environments. To date, this program has yielded prototype power supplies that deliver regulated dc power at power densities of 12 W per cubic inch and weight densities of 200 W per pound. Operating efficiencies of the prototype units are currently in the 60- to

80-percent range, depending on the specific topology and output voltage levels. Figure 4 compares a prototype module with an equivalent contemporary power supply design.

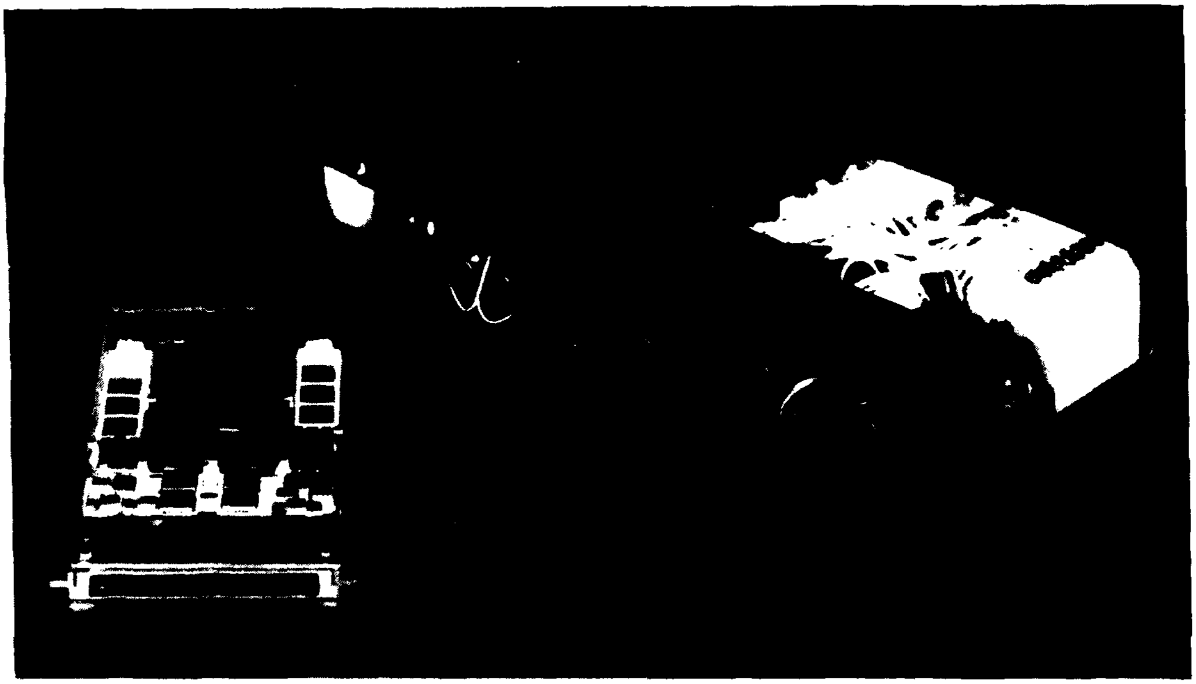


Figure 4. High-density power supplies compared to equivalent contemporary design

By 1987, TI Plans to have full military-qualified, off-the-shelf, standard power supply modules available to support future avionics power requirements. Power densities for the late 1980s are projected to be in the range of 20 to 30 W per cubic inch and weight densities are projected to exceed 400 W per pound. Operating efficiencies of the power supply modules are expected to be in the 75- to 85-percent range, given that the equipment requirements are typical of existing equipments. The standard power supply modules (250- to 500-W delivered power range) have a predicted MTBF exceeding 50,000 hours. Table 3 summarizes contemporary and projected power supply capabilities.

Table 3. Power supply capabilities

Parameter	1982 Production technology	1983 Prototype technology	1987 Production technology
Power density (watts/cubic inch)	1-2	10-12	20-30
Weight density (watts/pound)	40	200	400
Efficiency (percent)	60-80	60-80	75-85
Reliability (MTBF, hours)	10,000	20,000	·50,000

SYSTEM CONFIGURATION DRIVERS

Availability - Statistical data accumulated by the Air Force and Navy show that our current front-line airborne weapon systems exhibit not-mission-capable (NMC) rates of 25 to 35 percent, primarily owing to equipment failures and maintenance actions. This means that the military services must procure and maintain approximately 30 to 50 percent greater airborne weapon system resources to accomplish their missions than would be needed with ideal availability (100 percent). The primary avionics equipments (i.e., instruments, communications, radio navigation, fire control, and ECM systems) are responsible for 5- to 8-percent NMC rates or approximately 20 to 25 percent of the total aircraft equipment failures and maintenance actions. Thus, major improvements in reliability, maintainability, fault tolerance, and diagnostic capability are absolutely essential for new airborne weapon systems and, in particular, the avionics equipments, because of the adverse life-cycle cost (LCC) impact that results from the nonavailability of weapon system resources.

The order-of-magnitude increases in radar system reliability are predicted based on the following active array design features:

- o The basic fail-soft nature of the array, wherein up to 5-percent module failures are tolerable with acceptable performance degradation
- o T/R module design and production aimed at extremely high reliability (100,000 hours).
- o Incorporation of functional element level and/or higher level redundancies in the radar power supply, processor, and signal generation/conditioning subsystems.

Flexibility - The selected radar system design approach must provide the inherent flexibility and hardware resources needed to comprehend the multimode/multirole operational requirements for future airborne radar applications. These requirements encompass the various mission scenarios, air-to-air and air-to-ground modes of operation, and enemy threat characteristics (including active and passive ECM) envisioned for the ATF and VFMX weapon systems. THese diverse requirements place stringent demands on the radar system performance characteristics, operating modes, and weapon delivery capabilities. However, the logistics and LCC benefits that accrue through commonality of radar hardware will demand that the 1990s radar system either incorporate the full capabilities needed or be software-reconfigurable to satisfy these multimode/multirole requirements. TI views a solid-state phased-array radar as the most promising candidate for the 1990s because of the inherent flexibility and potentially favorable performance and affordability characteristics of this radar technology.

Survivability - The Warsaw Pact forces of the 1990s are expected to deploy dense, highly sophisticated air defense networks that will be fully integrated for effective, coordinated defense against air strikes by current and future generation airborne weapon systems. These air defense networks will represent a formidable threat to the survivability and operational effectiveness of advanced airborne weapon systems. The multimode functional and performance requirements imposed by multirole missions and the predicted enemy threat drive the 1990 radar system design to technology-intensive solutions to effectively counter the threat. We believe that technological innovations are the principal means for solving these operational problems.

The new radar technologies will yield hardware resources that support the aperture flexibility, signal-processing power, damage tolerance, and nuclear hardening needed for a feasible solution to the predicted 1990 multimode/multimission operational requirements. However, new innovative radar signal-processing concepts and advanced algorithms still must be developed to achieve greatly improved ECCM and LPI capabilities that are essential in all radar modes for acceptable weapn system survivability. In this regard, there are recognized needs for substantial improvements in low observables capabilities compared to operational airborne radars in the inventory. TI believes that RF emission control (EMCOM), low radar cross-section (RCS) design of the aperture, and LPI waveform design requirements will be major design drivers for the airborne radar systems of the 1990s.

Affordability - TI views the major elements of active-array radar system development to be cost, reliability, performance, and compatibility with the future multimode/multirole airborne radar system applications. The selected radar system design approach must be based on comprehensive LCC versus performance tradeoffs that will lead to affordable hardware solutions for future applications. In this regard, the key LCC considerations for the array system are an order-of-magnitude improvement in reliability, maintenance-free operation, and a producible design. The selected design approach must also provide flexibility for incorporation of future technology advancements that could further reduce LCC.

We believe that there are two main technical objectives to be addressed in the development of solid-state phased-array radars:

- A cost-effective approach to solid-state T/R module fabrication

- Development of solid-state phased-array apertures with demonstrable LCC savings and new/improved system capabilities compared to mechanically scanned antenna and passive array airborne radar systems.

Several major elements are associated with developing a cost-effective module. For example, the key module-level considerations of cost, reliability, producibility, device/module production and test facilities, and the module design and production schedules must be rigorously addressed. In addition, the module performance must be compatible with the required array system performance for a balanced, high-performance, cost-effective design. Achieving module cost reduction goals will be a critical design and fabrication consideration because module cost will have a large bearing on the system-level performance/cost tradeoffs for future solid-state phased-array radars. Key thrusts to achieve the needed module cost reductions include the development of simplified T/R modules using monolithic circuit technology and the development of advanced manufacturing technology for low-cost production of the T/R modules. TI is currently engaged in these efforts through our AFWAL-funded Manufacturing Technology and Advanced Solid-State Radar Module Development programs.

Design of the solid-state array for an order-of-magnitude reduction in maintenance support cost is also a chief design driver. The array design should be such that no organizational level or intermediate level maintenance is required. Since the array is digitally controlled, effective digital BIT and fault isolation concepts are possible to determine the operational status of the array. Thus, it is possible to eliminate the need for array flight-line and intermediate shop test equipment for an operational system, which would be a considerable savings in support cost.

RADAR SYSTEM ARCHITECTURES FOR THE 1990s

In the past, available technology and design criteria (i.e., minimum weight, volume, cooling, prime power, procurement costs, etc.) have led industry to produce airborne radar designs that, in effect, were prone to fail. For example, contemporary radar systems generally contain the minimum number of components needed to achieve the desired functions. Consequently, single component failures often lead to complete loss of capability.

Within the decade, however, technology will permit innovative system and design engineers to produce airborne radar equipments that provide true multimode/multimission performance capabilities at affordable costs with an order-of-magnitude improvement in system reliability compared to existing airborne radars. The key technology developments are GaAs microwave devices, VHSIC, advanced processor and receiver/exciter architectures, and highly reliable high-density power supplies.

Technology advances in these areas have now reached the point where we can forecast with confidence a revolutionary change in airborne radar system architectures. The new architectures will incorporate redundancies at the functional element level with an affordable impact on radar system size, weight, power, and cost. Figure 5 illustrates a candidate system design

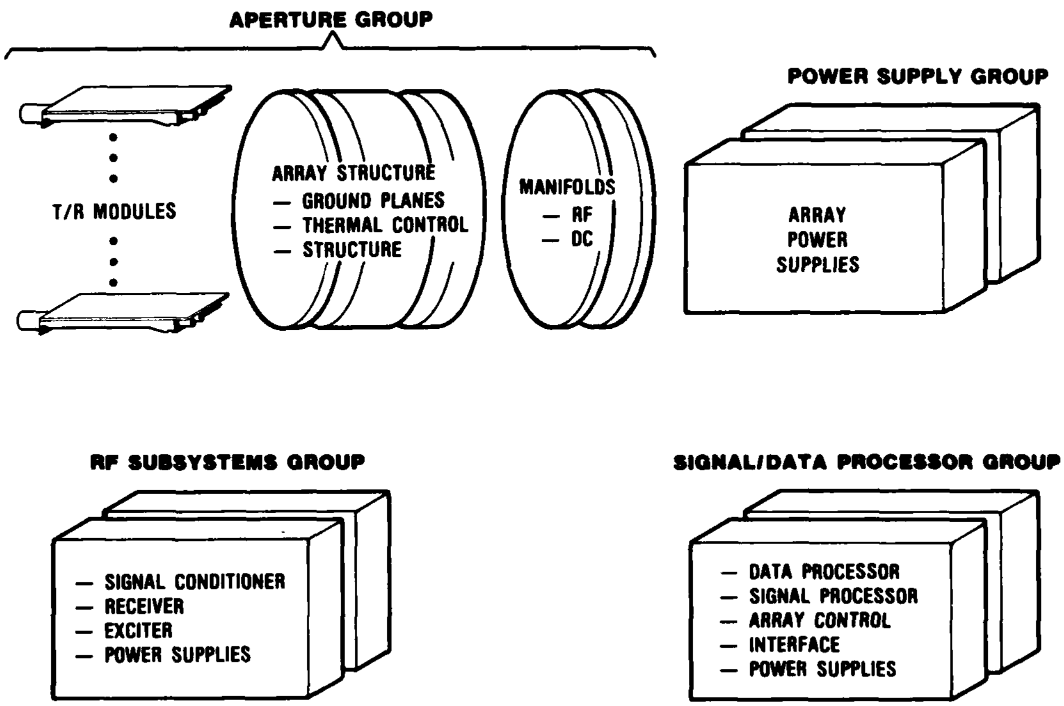


Figure 5. Radar system configuration for the 1990s

for the 1990s that provides multimode/multirole radar capabilities with a predicted mean time between failure (MTBF) approaching 2,000 hours. The forecasted radar configuration consists of a solid-state active-element aperture, a power supply system, a signal generation and conditioning system, and a digital group capable of substantial data and signal processing.

Two principle factors influence the overall reliability of a system. One is the inherent reliability of the basic components and the other is the degree of redundancy in the system architecture. The first factor depends on technological developments in materials and devices. The second factor is driven by the functional requirements and cost constraints of the specific system application.

Reliability predictions for the candidate radar system architecture are based on our technology forecasts of the late 1980s. Additional reliability improvements are projected for the mid-to-late 1990s, based on further advances in technology and architecture. However, MTBF values for the late 1980s provide a reasonable lower limit for operational values of the 1990s. Figure 6 summarizes the reliability functions and the corresponding MTBF predictions for the major subsystems and the total candidate radar system configuration. The predicted MTBF for the complete radar system is 1,698 hours.

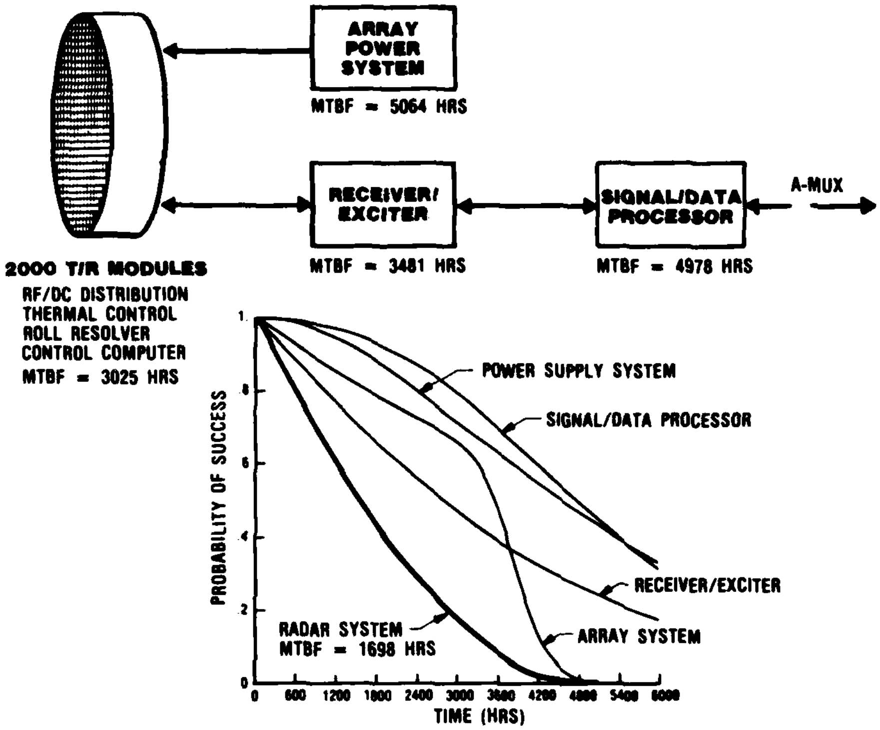


Figure 6. Candidate radar system reliability

New Threat Technology Impact on Avionic Systems

S.D. McGregor and G.R. Henderson
Rockwell International, Lakewood, CA

An assessment of the vulnerability of avionic systems to directed energy, chemical and biological weapons. Current threat level degradation effects on avionics systems and protective hardening techniques are discussed. The use of computer codes to assess vulnerability of hardened systems is described.

STAR - A Multiple Frequency Approach to Fire Control Radar Performance Improvement

C.G. Storruste, Naval Weapons Center
China Lake, CA

and

D.D. Riggs, Hughes Aircraft Co.
El Segundo, CA

A new multiple frequency radar concept is being developed and demonstrated which will counter the constantly increasing capability of the enemy to interfere with airborne fire control weapons system performance. Simultaneous Transmission and Reception (STAR) of several widely spaced frequencies force hostile jammers to spread available jamming power over a wide bandwidth, thereby reducing enemy jamming effectiveness.

Adaptive Multifunction Antennas for
Tactical Fighter Aircraft

J. Earl Jones, Air Force Wright Aeronautical
Laboratories (AFSC) AFWAL/AAAN
Wright-Patterson AFB, OH 45433

Steve Spurlin, George Rassweiler
Harris Corporation, P.O. Box 37
Melbourne, FL 32901

The expanding role of high performance tactical fighter aircraft in the modern battlefield environment has resulted in requirements of essentially a proliferation of new avionics terminals, many of which are currently in advanced/engineering development. When completely developed, terminals such as Global Positioning System (GPS) User Equipment, Joint Tactical Information Distribution System (JTIDS) receivers, Identification Friend of Foe (IFF) transponders, modified SEEK TALK voice communication receivers, Precision Location Strike System (PLSS), PAVE MOVER (and evolving JSTARS terminals), threat warning systems, etc., will provide such aircraft with a wide variety of unique (although sometimes overlapping) communications, navigation, identification (CNI), and other offensive/defensive avionics capabilities.

Some of these terminals will be implemented with spread spectrum techniques to provide some degree of antijam (AJ) protection. However, the advent of enhanced enemy jamming capabilities in recent years has led to the initiation by various defense agencies, of numerous adaptive null-steering antenna system technology development programs to supplement spread spectrum AJ protection. Although such antenna systems will greatly improve electronic-counter-counter-measures (ECCM) capabilities, it should be noted that these adaptive antenna developments have each addressed only a single function terminal, and thus, have been optimized to the projected threat, frequency, and waveform of that terminal. Deployment of this formidable aggregation of just new terminal equipment (not to mention single function adaptive antenna systems) on future tactical fighter aircraft is expected to be costly, present a space problem on the aircraft, and give rise to the problem of how to maximize the utility of these new terminal functions while minimizing the loss of fighter aircraft operational performance due to increased maintenance complexity, weight, competition for pilot attention, and (in the case of antenna systems), aerodynamic drag and radar cross section.

Clearly, an integrated, top-down approach is necessary to address these issues. The AFWAL Integrated Communications, Navigation, and Identification Avionics (ICNIA) effort is addressing some of the integration issues - those associated with CNI terminals. A more difficult problem occurs when one attempts to

integrate antenna functions, because both integrated antenna electronics (algorithms and control logic) processors and integrated antenna aperture issues need to be addressed. Specific antenna aperture issues include band partitioning (L, C, X, K_u, K_a, etc.), available airframe locations, coverage requirements, transmit/receive versus receive-only requirements, etc. THe ultimate design of an integrated antenna system will be mission, threat, and airframe dependent - these requirements will in turn dictate antenna control logic requirements and design.

To address the issue of integrated antenna systems for tactical fighter aircraft, the AFWAL Avionics Laboratory initiated the Adaptive Multifunction Antenna (AMA) program in August 1981. The objective of the AMA program is to provide cost-effective solutions through the development of unified adaptive array antennas which can serve multiple avionics terminals in a flexible, reallocatable manner, while providing an across-the-board increase in avionics ECCM performance. Major emphasis is currently on the development of an L-band AMA to interface with JTIDS, GPS, and IFF terminals on a tactical fighter aircraft.

This paper will summarize the results of the effort to date, to define AMA performance requirements and to demonstrate feasibility. Topics to be presented include:

Synthesis of an L-band CNI avionics systems consisting of CNI terminals, the L-band AMA, *and an independent system* controller;

Definition of AMA performance in tactical fighter mission scenarios via simulation and component measurements;

Theory, design and brassboard demonstration of an AMA for L-band CNI terminal applications, to include the presentation (to the extent feasible) of experimental measurements of L-band aperture performance on scale models of a tactical fighter aircraft;

Life cycle cost considerations for a CNI avionics system which includes the AMA

Synthesis of the L-band AMA for a tactical fighter aircraft required the involvement of the aircraft manufacturer. Since aircraft adaptive antenna installation costs usually exceed product costs, such involvement is considered crucial to the success of this effort if cost effective AMA designs are to be realized. The involvement of the aircraft manufacturer in AMA design synthesis will therefore also be discussed.

ASD 83-1055

Infrared Search and Track System for Air Warfare

Lt. D.A. Rardin, USAF
Avionics Laboratory, WPAFB, OH

Infrared Search and Track System (IRSTS) are now under development by the Air Force. The managing office is in the Avionics Laboratory at Wright-Patterson Air Force Base. Four members of the Air Superiority Group (AFWAL/AART-1) handle general management, contractors, and testing for this Advanced Development Program (ADP). This paper covers the problems which generated the need for an air-to-air sensor such as this, a brief IRSTS history, our program objectives, our scope, results and continuing activities.

THE PROBLEM

The threats of today and the future are evolving into low radar cross section vehicles which limit radar detection by interceptor radars. The strategic class of aircraft are designed to fly high at super velocities and the tactical aircraft fly low, within the ground clutter. In both scenarios they now have the capability of providing a high level jamming screen. Now, add numerical superiority and the resultant complexity to each mission. It becomes vital that the pilot maintain a high situational awareness with a minimal workload. We would also like to operate covertly.

To rise to these problems we need a covert system providing longer detection ranges along with the target information currently provided. The derived sensor must also be simple to operate and understand. This IRSTS is intended to be such a sensor.

IRSTS HISTORY

Ours, however, is not a new concept. There is a 20 year history leading to this sensor and its technology. While the previous IR sensors met the problem's covert requirements, they usually displayed raw video to the pilot and so greatly increased his workload. Their detection ranges could vary, depending on the pilot's ability to distinguish targets from clutter. This also led to a large number of false alarms and limited faith in some system's abilities.

To recover from the above shortcomings, we have designed a sensor which displays synthetic targets with low false alarm rates using established operational procedures. Today's IRSTS combats tomorrow's problems by meeting the following objectives.

PROGRAM OBJECTIVE

The program objective is to build a sensor capable of providing:

Covert Operation in a jamming environment.
Long Range detection with multiple target tracking.
Threat assessment and prioritization.
Affordability; operationally and logistically.

By using passive sensing in infrared frequencies followed by extensive signal processing, we have met the covert requirement and overcome jamming.

The long detection ranges, driven by the problem, are provided by careful optical design and sensitive detector materials in concert with clutter discrimination to decrease false alarms. The increased faith in targets being genuine lightens the pilot's stress.

Because of the intense IR radiation of the high fast threat, an IRST system can provide the needed long range detection capability. It performs this task on both large and small radar cross section targets. Detection range at low altitude is much less than for the high altitude threats because the threats fly slower, radiating less IR energy, and the atmopsheric attentuation is greater. However, the IR detection range is still greater than radar burn through in an ECM environment. Once detected, each target is tracked and accompanied by information indicating threat.

These data allow the system to prioritize the targets based on the threat assessment, again easing pilot workload.

Finally, through forward-looking planning from its inception, this program may easily transition to production saving many costly, intermediate stages. The systems are designed to allow modules to be replaced as new technology becomes available in optics, detectors, and signal processing. Interface-wise the sensor mimics current radars in both symbology and controls, simplifying pilot learning.

SCOPE

This program's scope covers the design, construction, integration, and testing of an IRSTS. The design, as mentioned, required a degree of modularity and off the shelf technology to minimize risks and cost. Construction follows proven manufacturing techniques with as few labor-intensive components as possible. Integration work provides for an elegant interface with existing avionics controls and displays. Simplicity was again emphasized. Testing is composed of stages, to be covered in continuing activities.

RESULTS

In the last stages of construction, all system designs have been finalized and flight test plans are nearly complete.

CONTINUING ACTIVITIES

Once the hardware construction is complete, the system will be tested and debugged as a unit. Up to this stage, only module testing has been possible.

Testing during the ADP will be in three stages: Laboratory, Rooftop, and Flight. The laboratory portion concerns component performance while the system is operated in a calibrated environment. Rooftop testing will provide insight to detection ranges and allow immediate, less costly modifications than possible during flight testing. Whereas the rooftop tests will be ground-to-air, our flight testing will provide air-to-air lines of sight identical to operational environments. This will also allow us to exercise the aircraft interface as well as our spectrum of clutter processing.

Following the Advanced Development Program tests, the system will enter Full Scale Developemnt for applications.

CONCLUSION

In summary, the IR Search and Track System will provide significant operational utility to air-to-air warfare systems while minimally increasing pilot workload. It will also, through continuing development, be a foundation for future aircraft sensors.

GCSS II: A Computer System Architecture Evaluation Tool

L. Hart, Naval Air Development Center
Warminster, PA 18974

ABSTRACT

GCSS II provides a design aid and evaluation tool for computer system architectures by measuring hardware utilization as a function of mission software and processor, memory and bus speeds. This paper presents a description of the simulator, its possible utilization in system development and its planned use in F-14 and P-3C avionics developments.

INTRODUCTION

A simulation tool called GCSS II (Generalized Computer System Simulator II) was designed to evaluate computer system architectures and bussing configurations for a wide range of systems. GCSS II consists of three program elements written in SIMSCRIPT II.5 and resident on the Naval Air Development Center's Central Computing System. The three elements consist of an interactive input file generator, the general simulator, and a timeline report generator.

The GCSS II provides a design aid and evaluation tool for proposed computer system architectures by measuring processor loading, bus utilization and memory utilization as a function of such factors as mission software, hardware interconnections, bus control schemes and hardware speeds. There is no level of detail imposed on the definition of the mission software. Software modules can be specified at a very high, functional level or at a very fine, microcode level, depending on the information available to the user or on the level at which the user wishes to simulate the system.

Although capable of modeling almost any type of computer architecture, be it centralized, federated, or distributed, GCSS II was designed with special emphasis of simulation of multiprocessor types of computer architectures. In these types of systems, one of the main design considerations is the effect of information transfer conflicts on the total system operation. This effect is not readily determined by the use of analytical models, so it is often estimated during the system design process based on past experience. Because GCSS II models the interactions between all devices in a system, the effect of resource contention can be measured and considered in the resource allocation and task partitioning phases of system design.

SIMULATION DESCRIPTION

The hardware of the computer architecture to be simulated must be expressed in terms of three general hardware types, processing elements, memory devices and data transfer devices. Those hardware devices which initiate task execution (mini-computers, terminals, etc.) are modeled as processing elements. Devices which serve as a data source and/or sink (semiconductor memory, disks, line printers, etc.) are modeled as a memory device. The channels of communication between the hardware elements (buses, RF channels, etc.) are modeled as data transfer devices.

The performance can then be measured in terms of how well the system resources match the execution requirements of the software flow for a representative mission scenario. Software flow is expressed in terms of modules. Module execution is initiated by satisfying one or more preconditions such as a successor to a previously executed module, the availability of required hardware, the receipt of a message from a module executed in a different processing element or on the status of a system level flag. Modules may also be defined as executing at a specific time or iteration rate. Also available to the user in specifying the software is the ability to define a file structure.

Analysis of the reports generated by GCSS II will indicate whether a proposed architecture can successfully accomplish its mission for the tested scenario. In addition, excess capabilities, such as underutilized processors, busses and memories, can be identified and quantized directly from the output reports. Conversely, heavily loaded hardware as well as system bottlenecks involving groups of devices can also be identified. Special system features, such as the executive functions and bus protocol can be designed into the simulation and the overhead effects can be ascertained by examining the output reports.

The output reports generated consist of a module summary, bus utilization statistics, memory utilization statistics and processing element utilization statistics reports. These reports are generated at the conclusion of the simulation and, optionally, at a user specified periodic rate during the simulation. The module summary will provide the average execution times and the number of times a module has been executed for each module. The bus utilization statistics will provide loading data for each bus while busy satisfying the data transfer requests. Similarly, the memory utilization statistics will provide loading data for each memory satisfying data access requests. The processing elements utilization statistics provide processor loading data and also provide the resource contention information. The time spent waiting for a bus, a memory or another processor to become available to service the resource request issued by a processor is included in these statistics for each processor in the system.

USAGE IN A SYSTEM DEVELOPMENT

As an example of how GCSS II may be used in a computer system architecture development, consider the P-3C Update IV and V development. It is desired to replace the CP-901 central computer system presently installed in the P-3C with a distributed processing computer system making use of a multi AYK-14 computer, multi-1553B bus structure. Figure 1 shows the proposed approach to develop the system architecture specifications.

The first task is to develop a functional requirements data base to include such items as control and data flow diagram, process and data descriptions, and operational requirements. With this data base and taking the availability of new technologies into consideration, a conceptual design with possible architecture alternatives can be defined. It is at this point in the system development that GCSS II will be utilized.

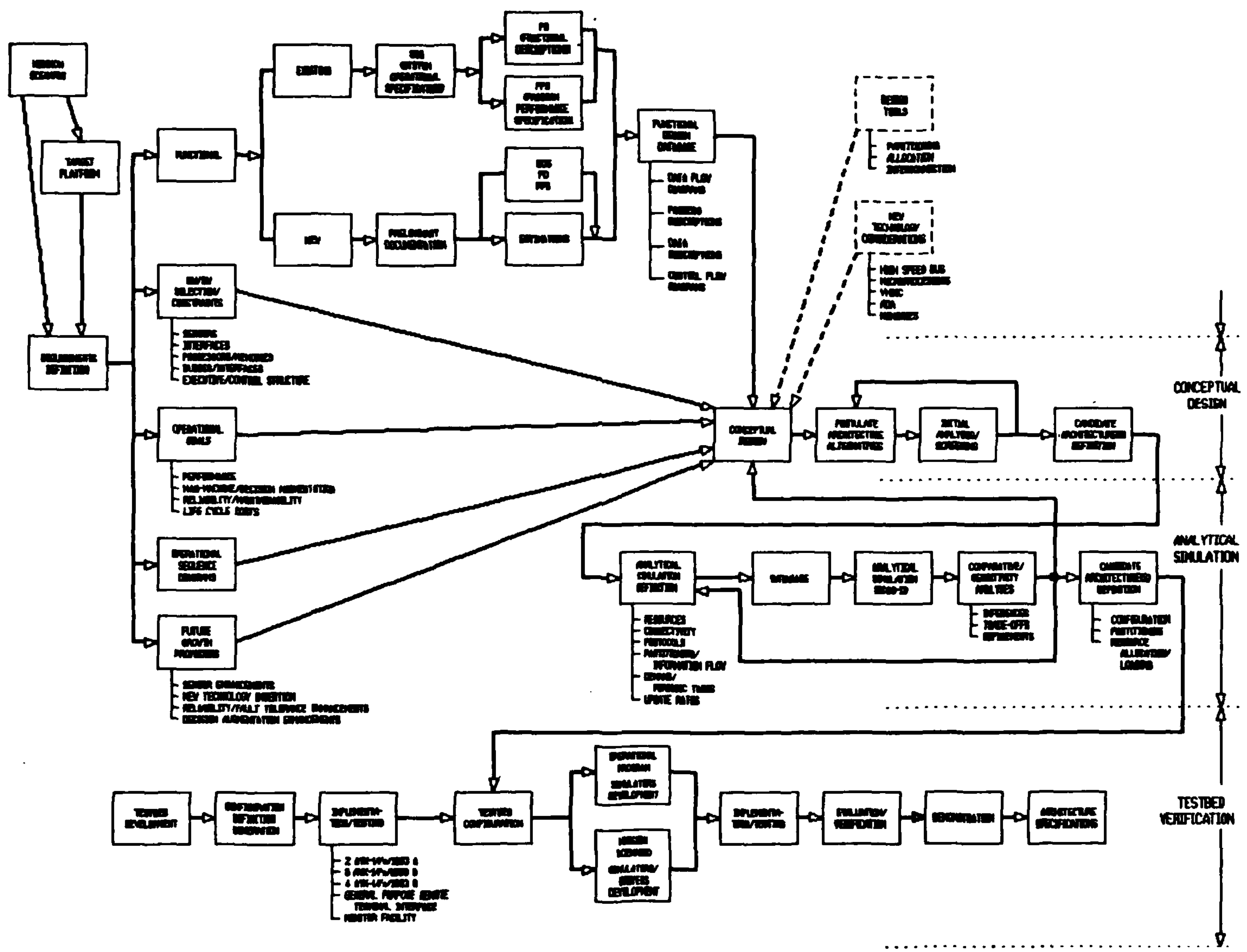
After an initial simulation model has been designed, alternative architectural features can be quickly evaluated by simple modifications of that model. Assuming the task flow remains fairly constant, changing hardware characteristics or even changing the device resources will not require designing an all new model. Also, the allocation of the tasks among the available resources can be varied to aid in fine tuning of the task partitioning process. GCSS II will provide the P-3C system designer with an analytical model of estimating system performance prior to building the hardware testbed.

The use of GCSS II in the F-14 AIP (Avionics Improvement Package) program is going to be more as an evaluation tool to monitor the system design efforts of Grumman Aircraft Corporation. At present, the AIP hardware has been modeled. The software is to be developed incrementally with twelve functional elements. As the program design specification for each functional element is delivered, that function will be incorporated into the simulation model. This will provide independent resource utilization estimates as each of the functional elements is developed. In FY-84, the first build T&E tape, which will include the system management, communication and navigation functions, will be incorporated into the simulation model.

OTHER GCSS II USERS

Aside from its possible use in the P-3C Update IV and the F-14 AIP projects, a number of other potential users are in the process of evaluating GCSS II for application to their project needs. The TACAMO project is planning to release an RFP for the avionics system development and are considering requiring the respondents to provide a GCSS II simulation as part of the proposal. NASA through a contract with Draper Laboratory is studying the simulator for possible use in developing general computer architectures for the various space platforms. NOAA in

FIGURE 1 ARCHITECTURE DESIGN/ANALYSIS/VERIFICATION PROCEDURE



Boulder, Co., is experimenting with GCSS II to aid in the design of a computer system to perform short range weather forecasting.

Multi-Source Integration Simulation
(IFFN/MILS)

John D. Parker, AFWAL, Wright-Patterson AFB, OH

and

Dr. Darroll S. McCormack
McDonnell Aircraft Company, St. Louis, MO

The tactical air-to-air mission and the counter-air intercept mission of the next fifteen years will be characterized by large numbers of high speed aircraft and many types and sizes of aircraft of diverse missions from both allied and hostile forces operating in close proximity to each other. In this environment, a single seated fighter aircraft with sophisticated avionics suite could levy a high workload on the pilot. Assumptions about the command, control and communications (C^3) environment will include conditions under which the fighter aircrews will be forced to operate with only their own resources. The introduction of improved fighter fire control systems and air-to-air weapons will establish an improved fighter weapon capability. With better fire control radar and weapon system capabilities expected in the near future, the only stumbling block to an expeditious weapon release against a detected and tracked aircraft which is within a valid launch envelope, will be target identification (ID). The ID criteria for missile launch may vary with the scenario and may include requirements such as: a) positively identifying a target as hostile; b) insuring that the target is not allied; and c) tailoring tactics to insure destruction of high value targets on a particular mission (i.e., bomber and attack aircraft).

The services have been seeking to perform system integration for target identification for several years, in several contexts, and for several mission areas. The AFWAL Avionics Laboratory has explored the issues for air-to-air identification for both fighters and surveillance aircraft, and preliminary design work has been done in both areas. The efforts have gone into some detail for the air-to-air fighter case. Areas of both system/avionics integration and control, here referred to as system fusion, and information combination issues, referred to as data fusion, have been explored in depth. The fullest benefits arise when both tasks are performed; however, data fusion needs further development before concepts that are being examined today may be fully implemented. In the meantime, today's equipment appears to be fully capable of supporting a level of system fusion for identification related equipment that may provide some very good improvements and capabilities, near term. Since many of the benefits are pilot-related, and become greater as the workload increases, any documentation and investigation of the area must exploit man-machine interaction as fully as possible, in an environment that is as realistic as possible.

The Air Force developed technology which allows one to bring all information bearing on the air-to-air identification problem together and effectively display the solution to the pilot. This process has been named Multi-Source Integration (MSI). The identification system integration will ultimately fuse information from cooperative and non-cooperative identification equipment, communication channels, passive electronic detection/identification equipment, and pre-briefed intelligence.

Initial fighter Identification Friend, Foe or Neutral (IFFN) fusion design studies provided for the development of a fusion algorithm for integrating the target identification sources into a unified identification subsystem. The feasibility analysis and validation of the algorithm has been conducted through analytical, non-real time simulation of representative fighter aircraft sensors and processing equipment to produce an estimate of the performance of this multi-source integrated identification system. These non-real time simulations have shown improvement in target identification capability, justifying the next logical step: performing a manned real-time simulation to assess the benefits of an automated ID system fusion process.

The Multi-Source Integration Simulation, also known as the IFFN/MILS Program, provided the first opportunity to evaluate real-time operation of the IFFN fusion concept under conditions close to actual operations. The overall goal of the IFFN/MILS simulation was to demonstrate how a near-term integrated identification system would operate under realistic conditions and quantitatively determine its benefits under a dense target environment.

The IFFN/MILS test was conducted utilizing McDonnell Aircraft Company's (MCAIR) simulation facilities. Specifically, these tests used two 40-foot diameter domed Manned Air Combat Simulators (MACS), four Manned Interactive Control Stations (MICS) and six computer-generated digital targets. The validity of using these types of simulation facilities for man-in-the-loop tests was proven during the Advanced Medium Range Air-to-Air Missile (AMRAAM) Operational Utility Evaluation (OUE). While IFFN/MILS contained a number of methodologies similar to those used during the AMRAAM OUE, it was smaller in scale. The simulation was designed to address the following objectives:

- o Demonstrate the mission utility of ID system fusion in a single-seat fighter aircraft including:
  - Investigate the capability of ID system fusion to increase range of ID, and
  - Investigate the ability of ID system fusion to reduce fratricide and increase survivability.
- o Investigate the marginal utility of different combinations of ID systems.

The Interplay of Cost and Performance Issues in Design of a New IFF System (Mark XV)

G.P. Nelson, W.A. Barnwell, R. Kowalski & E. Flamboe
Naval Research Laboratory
Washington, DC

The United States, in conjunction with some of its NATO allies, is embarked on a course to replace the current Identification Friend-Foe (IFF) system, with a new system known as Mark XV. This paper discusses several aspects of the IFF problem and includes both measured and projected data on system alternatives along with comparative cost projections for these alternatives.

EJS-High Anti-Jam Voice Radio System

Anthony L. Borelli and William E. Kirkpatrick
Hazeltine Corporation, Commack, NY

The Enhanced JTIDS System (EJS) is an advanced, secure, jam-resistant voice communication system under development by the Electronic Systems Division (ESD) of the Air Force Systems Command (AFSC) for the USAF Tactical Air Forces (TAF). EJS will permit the TAF to accomplish its mission in the presence of the projected severe and growing ECM threat of the Warsaw Pact nations.

The TAF are highly dependent upon voice communications between tactical aircraft, mission support aircraft, forward air controllers and elements of the Tactical Air Control System (TACS). Dependable voice communication is mandatory to effect the vectoring, confirmation of identification and weapon release in the volatile, rapidly changing tactical environment. The maximum jamming threat is likely to be encountered when TAF is engaged in Close-Air Support, Deep Interdiction and Offensive Counter-Air Missions. Other TAF missions having substantial voice communication contact are Search and Rescue and Defensive Counter Air. TAF identifies High Anti-Jam (A/J) voice communication as one of their highest priority programs.

The vulnerability of radio communications to jamming was clearly demonstrated during the 1973 Middle-East War. This precipitated the generation of a documented requirement (TAF ROC-321-75) and the CORONET CLEAR Study which resulted in the initiation of programs aimed at a near-term solution (HAVE QUICK) to counter the existing threat and a long-term solution (SEEK TALK then HAVE CLEAR, renamed EJS).

EJS addresses several key requirements identified by the Tactical Air Force including:

(1) <u>High Jam-Resistance</u> - To permit dependable communications in the presence of jamming, even when the desired signal-to-jammer range ratios are disadvantageous.

(2) <u>Voice Conferencing</u> - The ability to listen simultaneously to multiple audio signals transmitted from other platforms.

(3) <u>High Voice Intelligibility and Quality</u> - With quality specified to ensure a high degree of speaker recognizability.

(4) <u>Transmission and Message Security</u> -

(5) <u>Operational Flexibility and Ease-of-Use</u> - Similar to present AM radios with minimal network management procedures.

(6) <u>Low Cost</u> - To permit affordable widespread deployment.

EJS achieves its high jam resistance through a combination of techniques including spread spectrum modulation (direct sequence psuedo-noise/minimum shift keying, DSPN/MSK), fast frequency hopping, and an increase in transmitted power over the present UHF-AM radio. One influence of the Air Force MAJIC (Modular Anti-Jam Integrated Communication) Study on the system architecture resulted in the selection of the EJS frequency-hop rate, chipping rate and symbol packet as similar to the corresponding characteristics used in JTIDS (Joint Tactical Information Distribution System). In addition, the spread spectrum modulation type, MSK/CPSM (Continuous Phase Shift Modulation) and information modulation type (32-ary CCSK, Cyclic Code Shift Keying) are the same for both EJS and JTIDS. The particular characteristics chosen represent the best combination meeting the specified jam-resistance and the requirements for multiple independent links at command and control sites, while facilitating interoperability with JTIDS-equipped platforms and future integrated avionics configurations.

EJS will also include provisions to add a data link capability under subsequent Preplanned Product Improvement (P^3I), to achieve wider use of data by additional Air Force platforms. The selection of the EJS waveform as a JTIDS variant permits voice interoperability with suitably-equipped platforms of other U.S. Services and Allied forces.

EJS Radio Sets will be developed for tactical airborne, ground vehicular and ground transportable applications. Airborne command/control and man-portable sets are also planned. The EJS is expected to be deployed on 21 different types of ground and airborne platforms in quantities of several thousand sets.

The Hazeltine Corporation of Commack, Long Island, New York is the prime contractor for the Full Scale Development (FSD) phase of the EJS Program. Hazeltine is responsible for the design, development, fabrication and test of EJS for airborne and ground FSD platforms including the A-10 and OV-10 aircraft and the AN/TPS-43 and AN/GRC-206 ground platforms. Testing will include in-plant contractor tests and combined Government Development, Test and Evaluation (DT&E) and Initial Operational Test and Evaluation (IOT&E) effort. Subsequent production is planned leading to system deployment and use in the late 1980's.

F-14 Infrared Search and Track System Investigation

George K. Shamlian, U.S. Naval Air Development Center
Warminster, PA 18974

Advances in defense electronic countermeasures have highlighted the requirement for multi-sensor detection and tracking of targets by the F-14 in the fleet defense mission. One possible suite of sensors is the IRST in conjunction with the AWG-9 weapons control system radar. Via passive and/or active detection of targets and cross-correlation of target data, greater detection ranges, as well as raid count information, become possible. The objective of this effort was to invesigate potential IRST sensor candidates, range performance and overall effectiveness in the weapons control system.

A key IRST technical and performance consideration is the choice of spectral band. Candidate sensor characteristics and performance for two spectral regions and two time periods of availability - near and far term - were considered. The detection range performance of these candidate configurations was calculated for several threats in typical fleet defense scenarios. Large differences in detection ranges in the two bands can be observed for certain threats. Operational effectiveness analysis for a selected IRST candidate in conjunction with a selected radar improvement candidate showed the benefits of an IRST. Conclusions are drawn regarding the candidate sensors and technical issues relevant to further development and deployment of an IRST.

Surface Mine Detection Using an Airborne Infrared Laser Scanner*

W.A. Malila, D.C. Carmer and D.M. Zuk
Environmental Research Institute of Michigan
Ann Arbor, MI 48107

The deployment of anti-vehicular land mines is a well defined element of many scenarios practiced by potential enemy forces. While these mines may be either buried or placed on the surface, this paper deals only with the detection of surface mines, as might be deployed in support of rapid tactical offensive operations or hasty retreats and withdrawals.

Reconnaissance systems employing aerial cameras and passive infrared imaging scanners have capabilities for minefield detection, but are limited by requirements for daylight or for conditions producing detectable temperature differences. Active imaging systems provide other possible detection mechanisms which potentially are not as limited in daily hours of operation, due to their self-contained sources of radiation. This paper describes a limited flight experiment to test the concept of surface mine detection with a laser scanner. An experimentally configured airborne infrared laser scanner was flown over a test array of anti-vehicular mines and the resultant data were analyzed for mine detectability [1,2].

This experiment extended, to a flight environment, the results of a previous field measurement project that measured mine reflectances from a rooftop using active infrared sources [3]. In that rooftop experiment, both 10.6 μm and 1.06 μm lasers were employed and both produced specular returns from the mines, with lower background responses and better contrasts being observed at 10.6 μm.

An opportunity arose for obtaining 10.6 μm-laser scanner flight data by modifying a forward-looking active IR instrument on an ERIM aircraft so as to look downward in a flight-of-convenience experimental exercise. Both direct and heterodyne detection modes were used on flights over arrays of three types of mines deployed on a grassy background: PM-60 (painted plastic), M-15 (painted metal) and M-19 (unpainted plastic). The last two types are U.S. mines and the first is a simulated foreign type. Aerial photography and limited passive IR imagery also were collected.

Flights were made on offset flight paths over the arrays so that target responses could be analyzed as a function of scan angle or angle of incidence on the horizontally leveled mines. Nominal altitudes of 500 and 800 feet were flown. Response

*This research was accomplished under U.S. Army Contract No. DAAK70-81-C-0205, MERADCOOM, Fort Belvoir, VA 22060.

amplitudes were quantified and compared with rooftop measurements. An initial characterization of background signals was made and detectability of mines using a simple detection algorithm was studied. Image processing approaches were explored through application of the ERIM-developed Cytocomputer™, an image processing system that efficiently employs neighborhood processing operations through a parallel architecture.

Target responses exhibited a strong incidence-angle (scan-angle) dependence that was consistent with the previous rooftop measurements. Large signals were measured for cone angles of several degrees centered on the mines' surface normals. Since specific target detection rates (obtained using a simple detection algorithm) are classified they are not included here, but will be described in the oral presentation and may be obtained from References 1 or 2.

Histograms and standard statistical descriptions of background signals were computed and analyzed, as well as a measure that incorporates spatial variables. The latter was a table of run-length occurrences as a function of amplitude level, which can be conveniently computed using the Cytocomputer™. Also, use of spatial filtering to suppress background and other non-target signal variations was explored. Locally smoothed images were computed and subtracted from originals, producing difference images with enhanced target responses. The spatial filtering operations did not let extreme amplitudes from small-sized areas affect the local averages and hence did not comprise a strict averaging process. Substantial reductions in variance of the images were achieved, and the resulting difference images appear to be appropriate inputs for automated thresholding decision rules.

The active IR laser system performance results obtained, in our judgement, warrant additional investigation, including: (a) additional field or laboratory reflectance measurements, (b) determination of mine orientation distributions and (c) an examination of system aspects of such an approach for detecting surface minefields.

REFERENCES

1. Malila, W.A., D.C. Carmer, and D.M. Zuk, Investigation of Mine Detection Using an Airborne Infrared Laser Scanner (U), ERIM Report No. 158700-29-T, Environmental Research Institute of Michigan, Ann Arbor, MI, June 1982 (SECRET).

2. Malila, W.A., D.C. Carmer and D.M. Zuk, "Investigation of Mine Detection Using an Airborne Infrared Laser Scanner (U), Proceedings of the 31st National Infrared Information Symposium, Environmental Research Institute of Michigan, Ann Arbor, MI, pp. 451-486, May 1983 (SECRET).

3. Bornemeier, D., D. Carmer, H. McKenney and D. Zuk, Active Infrared Mine Detection Measurements (U), ERIM Report No. 138300-29-T, Environmental Research Institute of Michigan, Ann Arbor, MI, August 1979 (CONFIDENTIAL).

An Affordable Approach to an Advanced Countermeasures Decoy Dispenser System for Tactical Aircraft

J.C. Huber, Jr and E.E. Penix
Engineering Staff Members of the Goodyear Aerospace Corporation

ABSTRACT

The Goodyear Aerospace Corporation has, for the last several years, been involved in the development of an advanced expendable decoy countermeasures dispenser system for the self protection of tactical aircraft to replace the current AN/ALE-39, and the AN/ALE-40. As the developer of the initial chaff cartridge system (the AN/ALE-29) Goodyear has a 20-year history supporting the development of this low-cost electronic warfare system.

Despite the fact that chaff was first used 40 years ago this past August, the field of countermeasure dispensing is undergoing major changes and needs a new advanced dispenser system. The forces driving these requirements include the rapid proliferation of the number of threats, new decoy developments, stealth, and pilot workload. This latter requires a "Smart Dispenser" system which is capable of handling complex dispensing operations with a minimum of attention from the pilot or EW officer.

The advanced systems all grow out of studies conducted in the mid-70's. These studies found that significant savings and improved performance could be achieved by tying a threat processor, such as the warning receiver, and the dispenser system together with the processor doing some or all of the processing. Since the data on the threat is present in the threat processor and since modern warning receiver computers have the necessary capacity to handle the required processing, it is now practical to solve the EW problem with a combination of jamming and dispensing. Smart dispensing involves a three way set of considerations involving the warning receiver, the onboard jammer and the dispenser. Threats may be handled by silence, jamming, or dispensing—with the latter being the resource limited response due to the relatively few payloads which are available onboard each aircraft.

Only the threat processor can make all the necessary choices and these choices constitute a main workload of smart dispensing.

This being the case, one approach involves performing all the processing in the computer which is making the response selection; that is, the threat processor. The other approach involves a separate dispenser processor for these computations. (Inputs from other sensors are discussed in the classified slides.)

The affordability implications in software support, ground support equipment, reliability, maintenance support, and in initial acquisition are the key considerations in the evaluation of these two approaches. Other combinations involving the two approaches involve their ability to stand alone, or alternately the degree to which their architecture becomes intimately tied to the RWR.

Both are of course far preferable to manual systems which are not adequate for the pilot who is almost always dispensing when in real trouble or when trying to perform critical weapon delivery operations.

The concepts discussed here (which are architectural alternatives being implemented in the USAF AN/ALE-47) permit all the lessons learned in the MACE chaff trials and the EMBOW trials to be incorporated either in the threat processor or a dispenser processor in a situation sensitive manner. (Classified details are given in the viewgraphs.) In these Nato tests the Goodyear developed Rapport Compatible System was used to develop and test advanced concepts.

More importantly, as advanced tactics doctrine and optimum payload dispensing sequences are developed, they can be rapidly incorporated.

The prototype of a precursor AN/ALE-47 dispenser developed by Goodyear Aerospace is described and illustrated and test results are given. The heart of the system is a CMOS mechanization with advanced IC's and fabrication techniques. CMOS technology, first used by GAC for dispensers 14 years ago, are used with advanced PC board materials. These offer ease of fabrication, good mechanical structure, repairability, testability, a real way to avoid future parts obsolescence, and a low power/low thermal stress design.

In summary, the affordable dispenser system does not attempt to stand alone, but finds significant cost avoidance in the use of capabilities present in tactical aircraft. As described in the slides, the other elements in affordability involve advanced assembly techniques, careful attention to minimizing life-cycle costs in the area of reliability, operational simplicity, and in the repair/maintainability philosophy. As a current producer of one of the most reliable and cost effective aircraft dispenser systems ever built, Goodyear Aerospace has had and will continue to have a strong focus on affordability through quality.

Lessons Learned from TriService Avionics Standardization Programs

L.E. Rogers
Office of the Under Secretary of Defense,
Research and Engineering

The paper addresses on-going programs with specific examples and other related initiatives for improving avionics standardization among the services. It summarizes critical "lessons learned" in the management of TriService Material Standardization Programs; and the effect of these programs on both government and industry avionics managers in the long range acquisition and production planning.

END

FILMED

4-85

DTIC